Cold-Tolerant Eucalypts

Results of four trials in Lesotho

A.D. Leslie
Forestry Research Officer (TCO)

March 1992

Temo
ea
Meru

Research Section
Forestry Division
Ministry of Agriculture
Lesotho

CONTENTS

LIST OF MAPS, TABLES AND FIGURES

MAPS

TABLES

FIGURES

ABSTRACT

Four trials covering sixty two seedlots of twenty two species of cold-tolerant Eucalyptus species were established between 1979 and 1982 were assessed in late 1990 and early 1991. The results were compared with those at five years of the two trials planted in 1980, described in Richardson, (1985) and with the results from other countries with similar climates.

Those species most suited to the lowlands were E. nitens, E. stellulata, E. rubida, E. macarthurii and E.glaucescens. Unfortunately none of the trials were located in the foothills although E. nitens and E. stellulata are known to grow particularly well in this zone. Severe frosts in the mountains reduce survival of E. nitens to unacceptably low levels. In the mountains Tasmanian E. viminalis, E. nova-anglica, E. stellulata and E. dalrympleana have shown good growth and survival.

ACKNOWLEDGEMENTS

I would like to acknowledge the contibution of Mr K. Richardson, the first Forestry Research Officer, who was responsible for establishing the four trials.

Also, I would like to thank my fellow Research Officers Mr N. Maile and Mr J. Bazill for their considerable help with the assessments and the analysis. I would also like to thank the following Research staff for their assistance with field work and data entry into the computer: the Senior Research Forester, Mr M. Senekane; Research Forester, Mr T. Ramanyaka and the Assistant Research Forester, Mr T. Mpakanyane.

Most of the statistical analysis was undertaken by Ms J. Riley, ODA Biometrics Adviser and I am very grateful for her assistance.

INTRODUCTION

Eucalypts have been planted in Lesotho since about 1860, the first introduced species was probably E. globulus. Trees of this species about fifty years old were described by Heywood on his tour of Lesotho in 1908 (Heywood, 1908).

Large scale use of eucalypts in plantation conditions began with the Lesotho Woodlot Project (LWP) in 1973. Although a variety of eucalypt species had been used in the the LWP plantations; E. bridgesiana, E. camaldulensis, E. globulus ssp. maidenii, E. polyanthemos, E. rubida, E. tereticornis and E. viminalis only E. rubida was found to be satisfactory (Poynton, 1986). The planting of E. viminalis, E. tereticornis, E. bridgesiana and E. globulus ceased because of damage by Eucalyptus Snout Beetle (Gonipterus scutellatus) (Richardson and Meakins, 1986).

Although in recent years a larger proportion of pine, particularly Pinus radiata has been planted, the eucalypts remain important to the Government plantations programme. They also feature prominently in the establishment of community or private woodlots in Lesotho, as many grow quickly, produce good quality fuelwood and will coppice.

In an effort to diversify the eucalypt species used for plantations for fuelwood and poles the Research Section of the LWP and of its successor, the Forestry Division (FD) established thirteen trials of eucalypts, between 1979 and 1991.

The four trials described test in total sixty two seedlots of species and provenances considered to be very cold tolerant and also reasonably drought tolerant. Lesotho has an semi-arid climate with regular drought years and frequent frosts during winter. Species were chosen from areas in Australasia where climatic conditions were similar and from similar latitudes to Lesotho (Map 1). These include areas within the Australian Capital Territory (ACT), New South Wales (NSW), Victoria and Tasmania. Several Lesotho and South African land races were also included.

The four trials cover altitudes from 1 800 to 2 200m and were sited on soils derived from two geological formations, the basalts of the Lesotho Formation in the mountains and the sandstones of the Claren's Formation on the plateaux.

EXPERIMENTAL DESIGN

Three trials were randomised complete block designs. At one trial at Thaba Putsoa and another at Leshoboro Plateau, line plots of five trees, were replicated in ten blocks. The small size of the plots was necessitated by the size of the sites.

At Ha Ntsane twenty tree plots were used, replicated in four blocks. Unfortunately a lack of trees for some seedlots necessitated substituting a seedlot of E. rubida for some trees in plots. Thus some plots are a mixture of two species.

At the remaining Thaba Putsoa trial thirty two seedlots were tested in unreplicated plots containing twenty trees.

THE TRIALS

Due to severe land shortage for forestry and forestry research in particular the four trials described are small and the number of trees representing each seedlot are few. In addition they were not replicated in time, owing largely to lack of resources.

Thaba Putsoa (2200m)

Two trials were planted at a sheltered mountain site at Thaba Putsoa, one an unreplicated trial in 1979 (L/25/6) and the other a large replicated trial in 1980 (L/25/27). The site is situated on a steep, north-easerly facing slope which supports a shallow loam soil, of pH 6.4, between 250 and 600mm deep, derived from basalt parent material. Soil analysis indicated adequate concentrations of potassium and high calcium levels. Nitrogen levels are also thought to be high (Richardson, 1985). The original vegetation was dominated by Festuca spp. The site is sheltered and is not a typical mountain site.

Ha Ntsane (1880m)

The lowland trial at Ha Ntsane (L/25/9) is sited on the edge of a sandstone escarpment. It is on a slight south east facing slope with a clay-loam soil, derived from the underlying sandstone. A soil analysis was not undertaken for the site. The adjacent natural vegetation is an overgrazed grass sward with scattered *Chrysocoma tenuifolia* bushes.

Leshoboro Plateau (1800m)

The lowland site at Leshoboro (L/25/7) is located on a sandstone plateau which rises 200m above the surrounding plain. The trial was planted in 1980 on a site with a slight south facing slope. The soil is a sandstone derived sandy clay loam, of pH 5.6, between 1.5 and 2m in depth. Soil analysis of the top 200mm showed phosphorous at 2-3 ppm and a good supply of potassium at 125 ppm (Richardson, 1985). The site had been under arable agriculture for many years, but the natural vegetation was thought to have been grasses dominated by *Themeda triandra* (Jacot-Guillarmod, 1971 in Richardson, 1985). In 1979 a young compartment of *Eucalyptus viminalis* on the site was uprooted because of Eucalyptus Snout Beetle damage (Richardson, 1985).

The Leshoboro Plateau trial and Ha Ntsane trial were ploughed with a double pass of a Nardi plough. The Thaba Putsoa trials were pitted. Herbicide was not applied to any of the sites and fertiliser to all sites except the unreplicated Thaba Putsoa trial. The location of the trials are shown on Map 2.

THE SEEDLOTS

In total 62 different seedlots of 22 species were tested (Table 1). Those tested in each trial are listed in Table 2.

METHODS

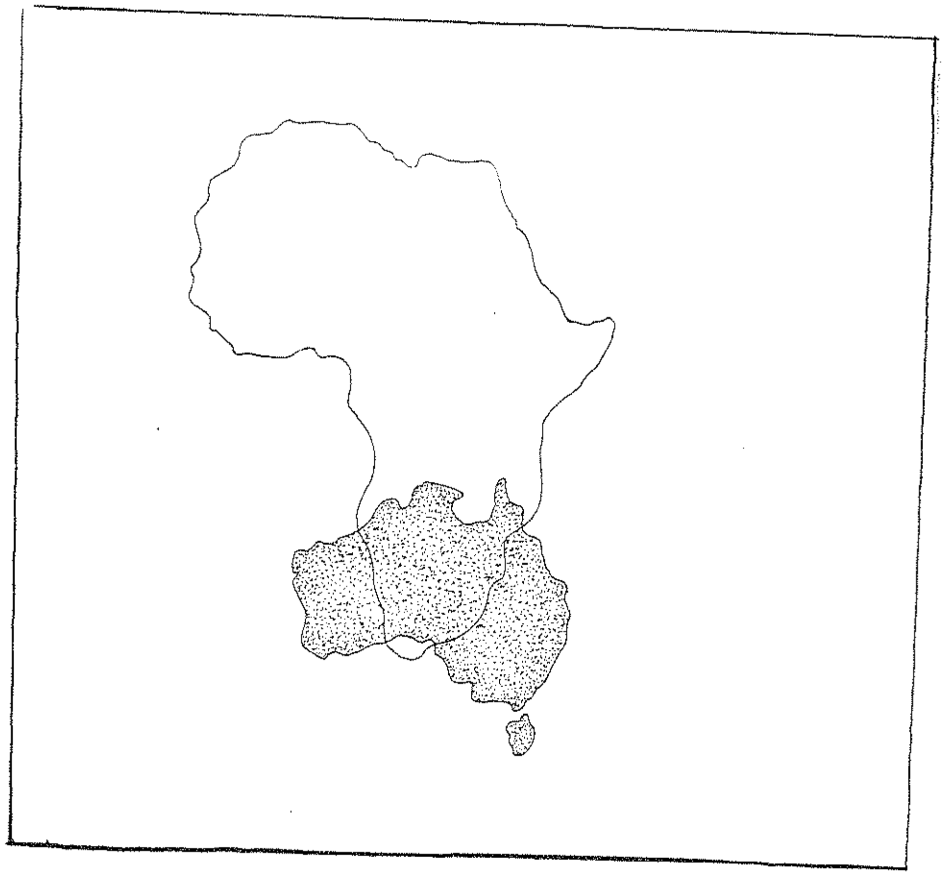
For all seedlots at all sites, diameter at breast height (1.3m), height, survival, straightness of stem, forking, branching intensity and branch thickness were assessed.

Diameter at breast height was measured and where there were more than one stem the average diameter was noted with the number of stems. Height was measured with a hypsometer.

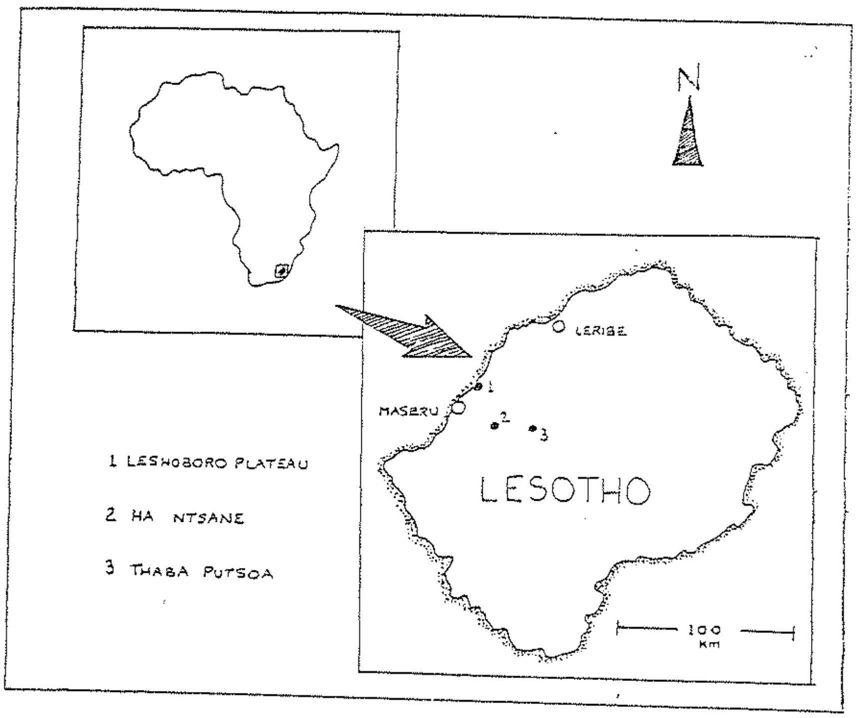
Form was assessed through a visual appraisal of stem straightness, forking, branching intensity and branch thickness.

Stem straightness was scored:

1 Straight
2 Slightly crooked
3 Very crooked



Map 1 Africa showing comparative area, latitude and position in Australia (adapted from Turnbull and Eldridge, 1983).



Map 2 Location of trials.

Table 1   Origin of Seedlots

Code	SPECIES	Seedlot No	Locality	ORIGIN Lat		Long		Altitude	Soil	No tree
1	E. badiensis	12090	Nimmitabel NSW	36	32	149	15	900	?	?
2	E. blakelyi	11819	Stuart Town NSW	32	48	149	5	300	?	?
3	E. blakelyi	11835	Mendooran NSW	31	50	149	6	450	sandy alluvial	?
4	E. bridgesiana	ex M' Hoek	Mohale's Hoek, Lesotho	30	10	27	28	1600	sandstone derived	?
5	E. camphora	9839	South Bomballa NSW	36	55	149	14	700	acid granites	?
6	E. camphora	11938	Wee Jasper S.F. NSW	35	7	148	34	830	?	?
7	E. camphora	12447	Connor Flat Uriarra ACT	35	21	148	52	760	?	
8	E. camphora	12448	Coree Flat ACT	35	17	148	49	1070	?	
9	E. camphora	12634	S. of Dederang VIC	36	30	147	3	450	?	
10	E. camphora	12315	Wee Jasper S.F. NSW	35	8	148	34	830		
11	E. chapmaniana	12304	Koseivsko Nat. Park NSW	36	10	148	14	1280	?	?
12	E. dalrympleana	9537	Steppes TAS	42	7	146	48	670		
13	E. dalrympleana	11721	Wiharega TAS	42	0	146	50	850		
14	E. dalrympleana	12097	Cotter Hut Area ACT	35	41	148	50	1100	red clays	?
15	E. deanei	11245	North East Tenterfield NSW	28	50	152	10	970	?	?
16	E. glaucescens	10841	Mount Tingi-Ringi NSW	37	0	148	40	1420	Ordivician slates	?
17	E. glaucescens	11253	Michelago NSW	35	35	149	17	1400	granite outcrops	?
18	E. glaucescens	13273	Mt St Gwinear VIC	37	50	146	21	1372	?	
19	E. glaucescens	13287	Guthega Koscuisco NSW	36	22	148	24	1550	?	
20	E. gunnii	11977	Shannon TAS	42	3	146	45	880	?	
21	E. gunnii	12583	Steppes TAS	42	7	146	48	670	dark grey	
22	E. gunnii	12864	Miena Central TAS	43	7	146	55	1000	Alpine humus	
23	E. gunnii	12956	Arthur's Lakes TAS	42	2	146	58	980	?	?
24	E. laevopinea	C747	Styx River S.F. NSW (Cpt64)	?	?	?	?	?	?	?
25	E. laevopinea	11653	Walcha NSW	31	11	151	26	1070	acid granites	
26	E. largiflorens	8646	Yantabulla NSW	29	20	145	0	120	black clay loam	?
27	E. macarthurii	10942	Bowrall ACT	34	30	150	24	670	grey loam	?
28	E. macarthurii	11821	Bowrall ACT	34	28	150	25	640	grey loam	?
29	E. macarthurii	12023	Marulan NSW	34	39	150	7	600	yellow brown sand	?
30	E. macarthurii	30946	Belfast State Forest, E Tvl (RSA)	25	40	30	1	1888	?	
31	E. melliodora	28784	Bloemhof, W Tvl (RSA)	27	39	25	36	1234	?	
32	E. neglecta	7339	Buckland River VIC	36	42	146	53	760	alluvial	
33	E. nitens	11814	Anembo NSW	35	45	149	27	1000	basalt	?
34	E. nitens	11861	Badja Mountain NSW	36	30	149	28	1400	acid granite	?
35	E. nitens	12102	Nojee VIC	37	48	146	4	960	friable brown loam	?
36	E. nitens	12107	Mt St Gwinear VIC	37	50	146	21	1175	rich brown loam	?
37	E. nitens	12155	Splitter's Creek, Bendoc VIC	37	12	148	52	1070	schist over clays	?
38	E. nova-anglica	10717	Ebor Area NSW	30	24	152	21	1210	acid granites	?
39	E. nova-anglica	11667	SW Walcha NSW	30	41	151	18	910	acid granites	?
40	E. pauciflora	10808	Jenolan District NSW	33	59	150	7	1070	sandstone	
41	E. pauciflora	12009	East Oberon NSW	33	30	149	50	1220	shale	
42	E. pauciflora ssp debeuz	8777	Jounama Peak NSW	35	32	148	18	1500	granite	
43	E. pauciflora ssp debeuz	9829	Mount Ginini ACT	35	32	148	46	1730	?	
44	E. perriniana	10840	6.4 km from Kiandra NSW	35	53	148	24	1500	?	
45	E. perriniana	12027	Hungry Flat TAS	0	0	100	0	609	?	?
46	E. perriniana	12442	5km from Smiggin' Hole NSW	36	22	148	24	1555		
47	E. rubida	11290	Oberon District NSW	33	42	149	52	910	clay gravel	
48	E.rubida	11866	Captains Flat NSW	35	37	149	28	980	brown clay loam	
49	E.rubida	12438	Niagia District NSW	31	8	160	32	370	granites	
50	E.rubida	28796	Belfast State Forest, E TVL (RSA)	25	40	30	1	18888	?	
51	E.rubida	ex M'Hoek	Mohale's Hoek, Lesotho	30	10	27	28	1600	sandstone derived	?
52	E. sideroxylon	12017	Goonoo S.F. NSW	32	0	130	0	73	solidic	
53	E. sideroxylon	11844	S.E. Gilgandra NSW	31	54	148	35	300	red sandy loam	?
54	E. stellulata	10443	Oberon District NSW	33	43	149	52	1210	?	?
55	E. stellulata	11287	E of Nimmitabel NSW	36	33	149	22	1100	?	
56	E. stellulata	12293	Gudgenby Area ACT	35	45	148	58	1000	?	
57	E. stellulata	12987	4km S of Jerangle NSW	35	54	149	22	1200	?	
58	E. viminalis	10073	Swansea TAS	42	0.5	147	45.5	700-800	?	?
59	E. viminalis	10811	Orange District NSW	33	20	149	14	1160	Tertiary Basalt	?
60	E. viminalie	11175	E. Scone NSW	32	0	151	19	1280	Tertiary Basalt	?
61	E. viminalis	11743	NNW Bruthen VIC	37	26	147	34	800	?	
62	E. viminalis	12282	Cotter Hut Area ACT	35	41	148	49	1100	Red Clays	?

Table 2 Seedlots in Each Trial

Code	SPECIES	Seedlot No	L/25/27 Thaba Putsoa	L/25/6 Thaba Putsoa	L/25/7 Leshoboro Pl	L/25/97 Ha Ntsane
1	E. badjensis	12090	1			
2	E. blakelyi	11819	2			
3	E. blakelyi	11835	3			
4	E. bridgesiana	ex M' Hoek		4	19	
5	E. camphora	9839	4			
6	E. camphora	11938	5	2	1	1
7	E. camphora	12447				2
8	E. camphora	12448		1	2	3
9	E. camphora	12634				4
10	E. camphora	12315				5
11	E. chapmaniana	12304		3	3	
12	E. dalrympleana	9537	6			
13	E. dalrympleana	11721	7			
14	E. dalrympleana	12097	8			
15	E. deanei	11245	9			
16	E. glaucescens	10841	10	5	4	6
17	E. glaucescens	11253	11	6		
18	E. glaucescens	13273				7
19	E. glaucescens	13287				8
20	E. gunnii	11977	12			
21	E. gunnii	12583		7	5	
22	E. gunnii	12864		8	6	9
23	E. gunnii	12956				10
24	E. laevopinea	C747		9	7	
25	E. laevopinea	11653		10		
26	E. largiflorens	8646		11	8	
27	E. macarthurii	10942		16	9	
28	E. macarthurii	11821	13	20	10	
29	E. macarthurii	12023	14	21	11	
30	E. macarthurii	30946		19	12	
31	E. melliodora	28784				11
32	E. neglecta	7339		12	13	
33	E. nitens	11814	15			
34	E. nitens	11861	16	13	14	
35	E. nitens	12102	17	14	15	
36	E. nitens	12107	18	15	16	
37	E. nitens	12155	19			
38	E. nova-anglica	10717	20	17	17	
39	E. nova-anglica	11667		18	18	
40	E. pauciflora	10808		22		
41	E. pauciflora	12009	21	23	20	
42	E. pauciflora ssp debeuz	8777				12
43	E. pauciflora ssp debeuz	9829	22			13
44	E. perriniana	10840				14
45	E. perriniana	12027				15
46	E. perriniana	12442				16
47	E. rubida	11290				17
48	E.rubida	11866		24	21	
49	E.rubida	12438		25	22	
50	E.rubida	28796			25	
51	E.rubida	ex M'Hoek	32			
52	E. sideroxylon	12107	23			
53	E. sideroxylon	11844	24			
54	E. stellulata	10443	25	28		
55	E. stellulata	11287	26	27	23	18
56	E. stellulata	12293		26	24	19
57	E. stellulata	12987				20
58	E. viminalis	10073	27			
59	E. viminalis	10811	28			
60	E. viminalis	11175	29			
61	E. viminalis	11743	30			
62	E. viminalis	12282	31			

If there was forking, its position on the stem or stems was noted:

1 No forking
2 Forking near base
3 Forking near top

This influenced the number of poles or posts the tree would produce.

Owing to uneven survival in the trials the plots were subjectively designated open or closed, depending on the amount of light reaching the plot trees. Then branch intensity and branch thickness were assessed and classified thus:

1 light branching	1 thin branches
2 moderate branching	2 medium thick branches
3 heavy branching	3 thick branches

ANALYSIS

For the randomised block trials at Leshoboro Plateau and the replicated trial at Thaba Putsoa an analysis of variance (ANOVAR) was used to investigate if there were statistically significant differences between the performance of seedlots. However, both these trials have plots which were either not planted or have been planted with alternative species. There were also plots with no survival.

Problems were encountered with analysing the data of the Leshoboro Plateau Trial and the replicated Thaba Putsoa Trial. The memory of the computer was found to be too small to conduct an ANOVAR using Statgraphics.

On the advice of the Senior Forestry Adviser, ODA the data were sent to Ms. J. Riley, the ODA Biometrics Adviser. A thorough examination of the data revealed that the distribution of the values was skew and the data had to be transformed to satisfy the conditions of an ANOVAR. For dbh and height a natural log transformation was used, whereas a square root transformation was applied to the stem number data. For survival an interactive data analysis was used, to determine whether survival was statistically dependent on block or seedlot.

Ms Riley advised against using a multiple range test, if significance tests were considered necessary. One suggestion made was t use t-tests on the means of interest. These were conducted on height data, comparing the seedlots with the best seedlot in terms of Yield Function.

Unfortunately neither dbh or height alone give a reasonable indication of differences in volume, when comparing multistemmed and single stemmed species. So, an ANOVAR was conducted on the Yield function as calculated from the manipulated data supplied by Ms Riley.

For the trial at Ha Ntsane and the unreplicated trial at Thaba Putsoa mean survival, diameter at breast height and height were calculated. Further analysis was not undertaken because of the mixture of species in many of the plots at Ha Ntsane and the lack of replication at Thaba Putsoa.

Yield Function

A Yield Function was used to rank the seedlots. The function was:

Height * Survival * $(dbh)^2$ * Number of stems per tree/ 1000

This roughly estimates the relative volume of a particular seedlot at a trial. Unfortunately, the function does not include a form factor for each seedlot or species.

Form

Parameters comprising stem straightness, forking, branching intensity and branch thickness were assessed. These were analysed to indicate which seedlots would be suitable for poles, fuelwood or both.

Mean Annual Increments

Using a general volume equation based on diameter and height of 682 Eucalypt trees an estimate was made of the Mean Annual Increment (MAI) for the seedlots at the Leshoboro Plateau trial and the replicated Thaba Putsoa trial. As this equation was largely based on volume, dbh and height relationships for E. rubida trees it can only be viewed as a rough estimate of MAI.

The formula used for estimating MAIs was:

MAI= Volume/ Age

Where Volume=

$(dbh)^2 * \text{Height} * (3.841*10^{-5})+0.005299*\text{No Stems} * \text{Stems/ha} * \text{Survival}$

Survival is expressed as a fraction rather than a percentage.

RESULTS

Results of Analysis of Height, Dbh and Survival

Results of dbh, height and survival are shown in Table 3 to 6 and MAI in Table 7. Those of the Leshoboro Plateau trial and the replicated Thaba Putsoa were back-transformed from those supplied by Ms Riley.

ANOVAR of the data from the replicated trials at Thaba Putsoa and Leshoboro Plateau show statistically significant differences (@ 5%) in height and dbh with seedlot and block. To examine these differences t-tests were conducted on the height data between the seedlots and the best performing seedlot in terms of Yield Function.

Table 3 Thaba Putsoa Replicated L/25/6 1991 Assessment

Species	Seedlot	dbh	No. Stems	Height	Survival
E. camphora	12448	9.4	1.37	8.9	80
E. camphora	11938	5.9	1.25	6.3	76
E. chapmaniana	12304	14	1.41	11	18
E. bridgesiana	ex M'hoek	5.6	1	6.3	62
E. glaucescens	10841	10.3	1.66	9.4	68
E. glaucescens	11253	14.5	1.2	10.4	44
E. gunnii	12583	15.6	1.17	13.2	54
E. gunnii	12864	12.2	1.02	10.8	36
E. laevopinea	C747	0	0	0	0
E. laevopinea	11653	7.2	1.16	7.4	12
E. largiflorens	8646	0	0	0	0
E. neglecta	7339	4.2	1.55	4.6	58
E. nitens	11861	25.3	1.13	14.6	18
E. nitens	12102	24.1	1	14.1	2
E. nitens	12107	19.2	1.11	13.2	24
E. nova-anglica	11667	15.7	1.14	11.2	90
E. nova-anglica	10717	19.6	1.1	11.6	92
E. macarthurii	10942	10.4	1.26	9.1	42
E. macarthurii	30946	11.4	1.18	8.4	48
E. macarthurii	11821	13.1	1.11	9.9	62
E. macarthurii	12023	12	1.23	9.5	52
E. pauciflora	10808	13.4	1.4	11.5	38
E. pauciflora	12009	14.5	1.17	10.4	52
E. rubida	11866	20.5	1.12	11.9	64
E. rubida	12438	14.1	1.14	10.9	32
E. stellulata	12293	15.1	1.79	11.7	66
E. stellulata	11287	15.1	2.24	12.7	86
E. stellulata	10443	14.9	1.43	9.2	70

Table 4 Thaba Putsoa Unreplicated L/25/27 1991 Assessment

Species	Seedlot	dbh	No. Stems	Height	Survival
E. badjensis	12090	16.3	1.38	9.8	20
E. blakelyi	11819	0	0	0	0
E. blakelyi	11835	0	0	0	0
E. camphora	9839	10.4	1.09	6.9	25
E. camphora	11938	13.1	1.6	7.9	80
E.dalrympleana	9537	20.9	1	14.1	40
E.dalrympleana	11721	18.8	1	13.1	60
E.dalrympleana	12097	20.9	1	13	60
E. deanei	11245	6.2	1	6	5
E. glaucescens	10841	13.3	1.43	9.6	90
E. glaucescens	11253	15.5	1.64	10.4	60
E. gunnii	11977	18.2	1.09	10.3	60
E. macarthurii	11821	12.9	1.45	7.2	65
E. macarthurii	12023	14.6	1.25	9.3	75
E. nitens	11814	25.9	1.64	11.3	10
E. nitens	11861	0	0	0	0
E. nitens	12102	0	0	0	0
E. nitens	12107	0	0	0	0
E. nitens	12155	0	0	0	0
E. nova-anglica	10717	12.2	1	7.7	80
E. pauciflora	12009	13.3	1.46	8	50
E.pauciflora ssp	9829	11	1.53	6.8	15
E. sideroxylon	12017	0	0	0	0
E. sideroxylon	11844	0	0	0	0
E. stellulata	10443	13	1.6	8.1	100
E. stellulata	11287	16.5	2.07	10.4	70
E.viminalis	10073	19.9	1.25	10.2	65
E.viminalis	10811	17.1	1	10.4	40
E.viminalis	11175	16.7	1	8.7	50
E.viminalis	11743	18.6	1	12.7	30
E.viminalis	11282	19.9	1.12	11.4	40
E. rubida	1	16	1.43	7.9	45

Table 5 Leshoboro Plateau L/25/7 1991 Assessment

Species	Seedlot	dbh	No stems	Height	Survival
E. camphora	11938	12.3	1.45	11.7	80
E. camphora	12448	13.7	1.53	11.1	54
E. chapmaniana	12304	14	1.25	12.3	24
E. glaucescens	10841	8.7	1.83	8.6	56
E. gunnii	12583	13.1	1.2	11	74
E. gunnii	12864	12.4	1.1	10.2	58
E. laevopinea	C747	3.4	1	5	2
E. largiflorens	8646	2.5	1.09	3.3	20
E. macarthurii	10942	18.1	1.13	13.1	72
E. macarthurii	11821	15.6	1.24	12.8	70
E. macarthurii	12023	16.6	1.3	13.4	72
E. macarthurii	30946	15.2	1.02	12.3	62
E. neglecta	7339	4.2	2.38	5.7	40
E. nitens	11861	21.4	1.08	14.3	88
E. nitens	12102	18.5	1.19	14.7	68
E. nitens	12107	20.6	1.35	14.8	52
E. nova-anglica	10717	16.2	1.1	12.3	94
E. nova-anglica	11667	16.3	1.12	11.7	72
E. bridghesiana	M' Hoek	11.9	1.06	9.6	72
E. pauciflora	12009	15	1.43	12.9	42
E. rubida	11866	17.2	1.09	13.5	70
E. rubida	12438	17	1	12.5	70
E. stellulata	11287	13.8	2.13	13.5	80
E. stellulata	12293	12.6	2.27	12.5	70
E. rubida	28796	19.4	1.11	13.5	69

Table 6 Ha Ntsane L/25/97 1991 Assessment

Species	Seedlot	dbh	No stems	Height	%Survival
E. camphora	11938	10.9	1.79	9.8	66
E. camphora	12447	9.7	1.96	9.8	88
E. camphora	12448	11.4	1.5	9.8	67
E. camphora	12634	11.7	1.47	10.2	51
E. camphora	12315	10.3	1.85	8.9	61
E. glaucescens	10841	11.8	1.7	7.9	66
E. glaucescens	13273	13.4	1.75	10.4	73
E. glaucescens	13287	14.6	1.53	10.7	61
E. gunnii	12864	12.6	1.6	11.1	71
E. gunnii	12956	12.9	1.58	11.1	81
E. melliodora	28784	10.8	1.36	9.1	64
E. pauci ssp deb	8777	11.9	2.53	10.6	53
E. pauci ssp deb	9829	10.8	2.16	8.9	42
E. perriniana	10840	10.7	1.96	8.6	75
E. perriniana	12027	12	1.92	10.6	61
E. perriniana	12442	11.8	1.76	9.9	71
E. rubida	11290	15.3	1.28	11	74
E. stellulata	11287	11.6	3.2	9.7	60
E. stellulata	11293	12.4	2.12	10.4	66
E. stellulata	112987	11	3	10.8	72

TABLE 7. MAIs at the Trials

Code	SPECIES	Seedlot No	L/25/27 Thaba Putsoa	L/25/6 Thaba Putsoa	L/25/7 Leshoboro Pl	L/25/97 Ha Ntsane
1	E. badjensis	12090	2.7			
2	E. blakelyi	11819	0			
3	E. blakelyi	11835	0			
4	E. bridgesiana	ex M' Hoek		0.7	4	
5	E. camphora	9839	0.9			
6	E. camphora	11938	6.8	1.2	7.7	6.6
7	E. camphora	12447				7.6
8	E. camphora	12448		3.5	6.4	6.1
9	E. camphora	12634				4.9
10	E. camphora	12315				5.2
11	E. chapmaniana	12304		2	2.7	
12	E. dalrympleana	9537	9			
13	E. dalrympleana	11721	10.2			
14	E. dalrympleana	12097	12.4			
15	E. deanei	11245	0.1			
16	E. glaucescens	10841	8.4	4.5	2.8	5.9
17	E. glaucescens	11253	9.2	4.3		
18	E. glaucescens	13273				10.9
19	E. glaucescens	13287				9.6
20	E. gunnii	11977	8.3			
21	E. gunnii	12583		7.4	6.3	
22	E. gunnii	12864		2.2	3.8	9.2
23	E. gunnii	12956				10.8
24	E. laevopinea	C747		0	0	
25	E. laevopinea	11653		0.2		
26	E. largiflorens	8646		0	0.1	
27	E. macarthurii	10942		2.1	12.6	
28	E. macarthurii	11821	4.5	4.4	9.8	
29	E. macarthurii	12023	7.1	3.36	12.5	
30	E. macarthurii	30946		2.4	6.6	
31	E. melliodora	28784				4.4
32	E. neglecta	7339		0.7	0.8	
33	E. nitens	11814	4.5			
34	E. nitens	11861 clumped		6.7	22.2	
35	E. nitens	12102 clumped		0.6	14.6	
36	E. nitens	12107 clumped		4.6	15.7	
37	E. nitens	12155 clumped				
38	E. nova-anglica	10717	3.7	16.2	12.2	
39	E. nova-anglica	11667		10.4	9.14	
40	E. pauciflora	10808		4.1		
41	E. pauciflora	12009	4	4.9	6.4	
42	E. pauciflora ssp debeuz	8777				9.4
43	E. pauciflora ssp debeuz	9829	0.8			4.6
44	E. perriniana	10840				7
45	E. perriniana	12027				8.3
46	E. perriniana	12442				8.1
47	E. rubida	11290				11
48	E.rubida	11866		12.9	11	
49	E.rubida	12438		2.9	9.2	
50	E.rubida	28796			14	
51	E.rubida	ex M'Hoek	4.9			
52	E. sideroxylon	12107	0			
53	E. sideroxylon	11844	0			
54	E. stellulata	10443	8.6	7.6		
55	E. stellulata	11287	15.3	20.4	16.1	11.8
56	E. stellulata	12293		11.6	11.8	10.4
57	E. stellulata	12987				13.3
58	E. viminalis	10073	12.1			
59	E. viminalis	10811	4.5			
60	E. viminalis	11175	4.6			
61	E. viminalis	11743	4.8			
62	E. viminalis	12282	7.4			

There were not significant differences in height between the best seedlot in terms of Yield function and most other seedlots (Table 8 and 9). At the P=5% level the heights of only two seedlots at Thaba Putsoa were found to be statistically different to the best seedlot. At Leshoboro Plateau the heights of four seedlots were found to be statistically different to the best performing seedlot. It was decided that combining height, dbh, number of stems and survival would give a better indication of performance.

For survival an interactive data analysis, (equivalent to a contingency table) was applied to the data. It was found that survival at Thaba Putsoa was strongly dependent on seedlot (X^2 significant @ the 0.1% level of significance). At Leshoboro Plateau large differences were found in survival (X^2 significant @ the 0.1% level of significance) between seedlots and blocks.

Results of Analysis of Yield Function

The ranking of seedlots by Yield Function are shown in Figs. 1 to 4. The Yield Function gives a rough indication of the relative volume produced by the various seedlots.

Examining the graphs of Yield function for the replicated Thaba Putsoa trial and the Leshoboro trial (Figures 1 and 3) differences in the performance of seedlots are more pronounced in the Thaba Putsoa trial. There was complete mortality of two seedlots at this trial. This is an indication of the differences in the severity of the winters at the two sites. The trees at Thaba Putsoa are subjected to much colder conditions than those at Leshoboro, although they receive more precipitation.

An ANOVAR of the Yield Function data showed there to be statistically significant differences @ the 5% level of significance between blocks and seedlots at both the replicated Thaba Putsoa and Leshoboro Plateau Trials. Graphs of 95% confidence limits for the means of each seedlot are shown in Figures 5 and 6.

Examining the graph (Figure 5) of 95% confidence limits for Thaba Putsoa, there are four seedlots that are not statistically different from the best performing seedlot, E. stellulata (11287). These four seedlots were E. rubida (11866), E. nova-anglica (10717), E. nitens (12102) and E. nitens (11861). For the first E. nitens seedlot the mean was much lower than the other seedlots, but the confidence limits were particularly large because of the few surviving individuals. Confidence limits for the other E. nitens seedlot were smaller.

The same graph for Leshoboro Plateau (Figure 6) shows three seedlots that are statistically not different to the best performing seedlot, E. nitens (11861). These were two other E. nitens seedlots (12101) and (12107) and a E. stellulata seedlot (11287).

Figure 1

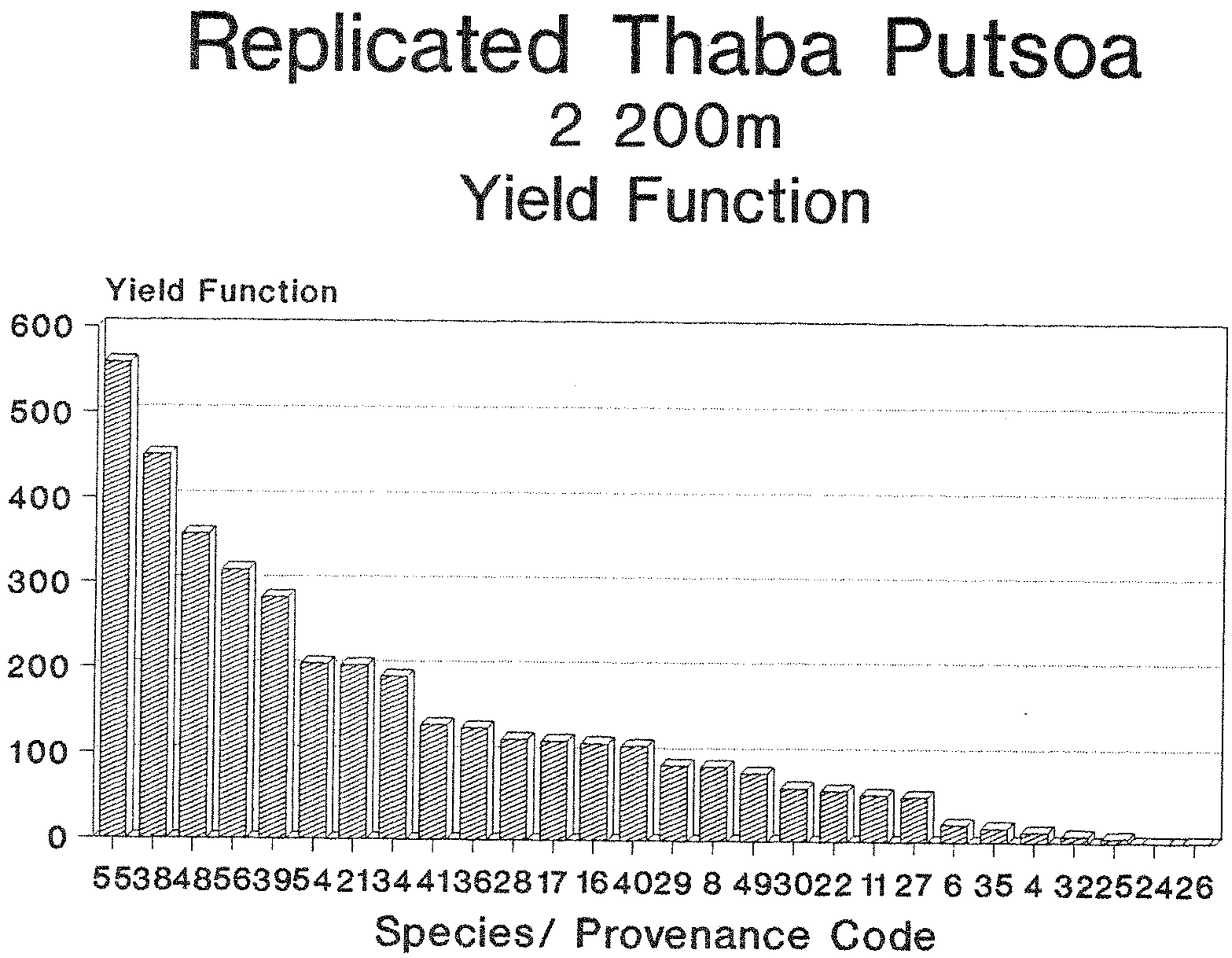

Replicated Thaba Putsoa
2 200m
Yield Function
Yield Function
600
500
400
300
200
100
0
55 38 48 56 39 54 21 34 41 36 28 17 16 40 29 8 49 30 22 11 27 6 35 4 32 25 24 26
Species/ Provenance Code

FIGURE 2.

Unreplicated Thaba Putsoa
2 200m
Yield Function

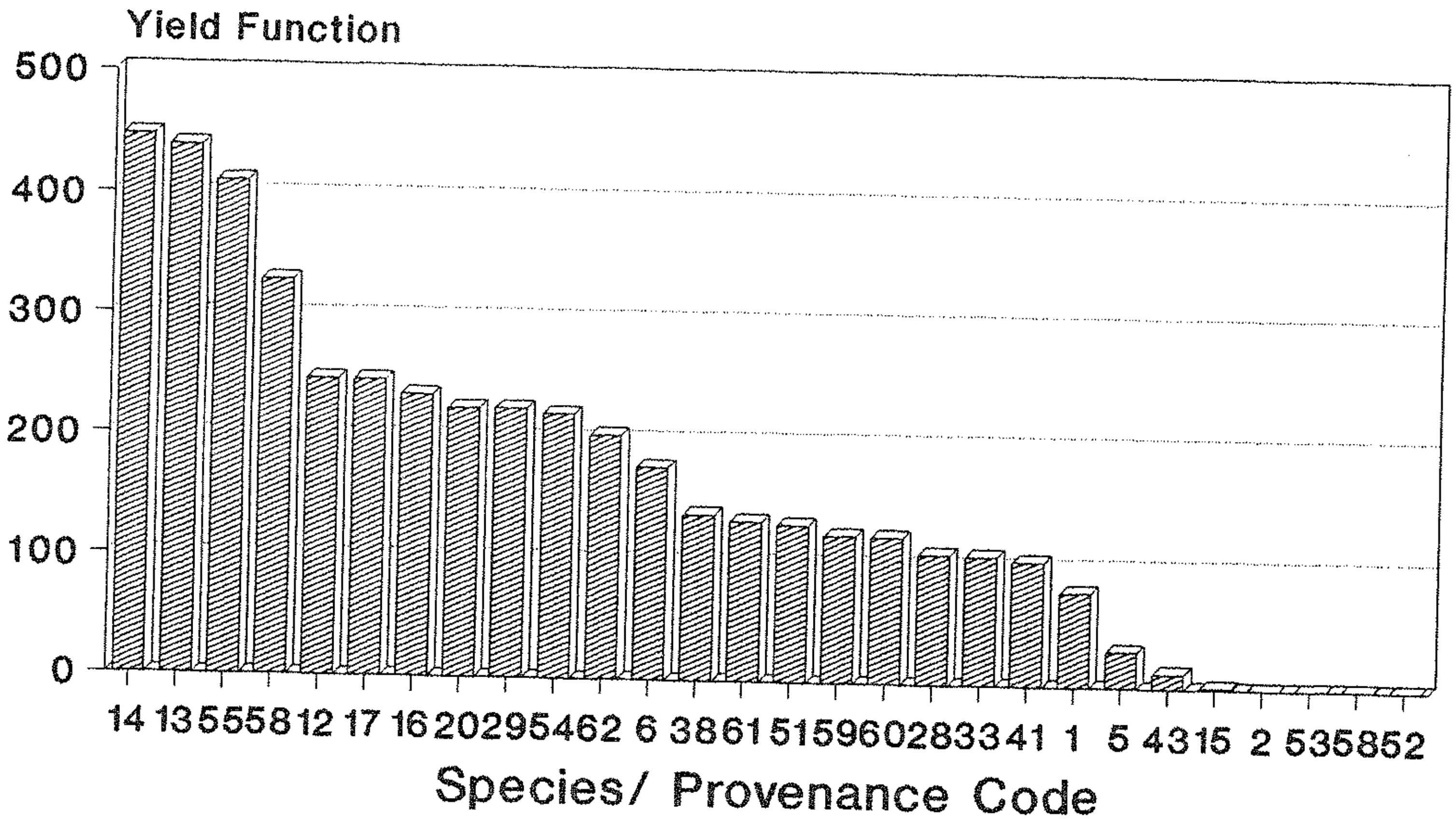


FIGURE 3

Leshoboro Plateau
1 800m
Yield Function

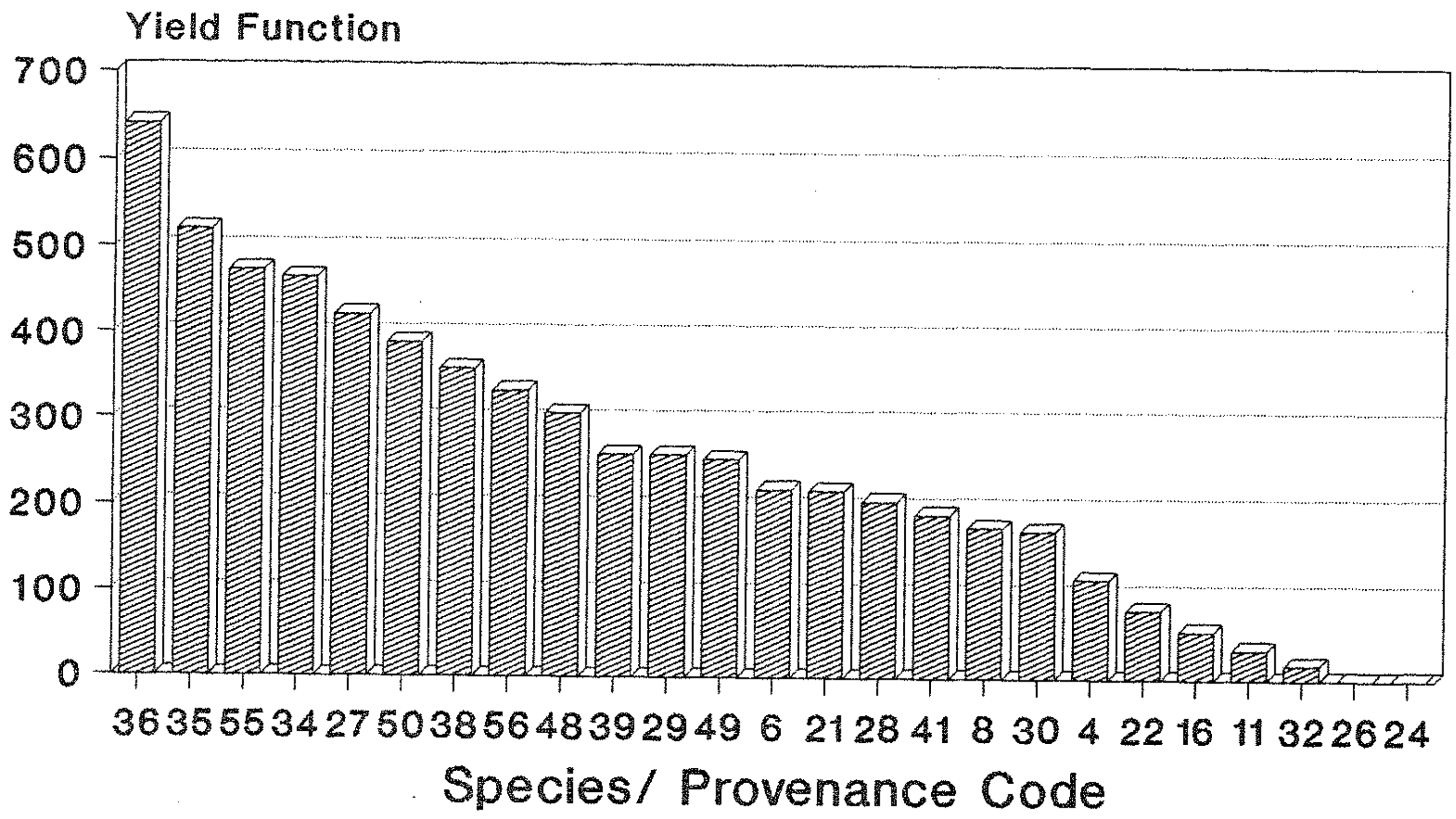


FIGURE 4.

Ha Ntsane
1 880m
Yield Function

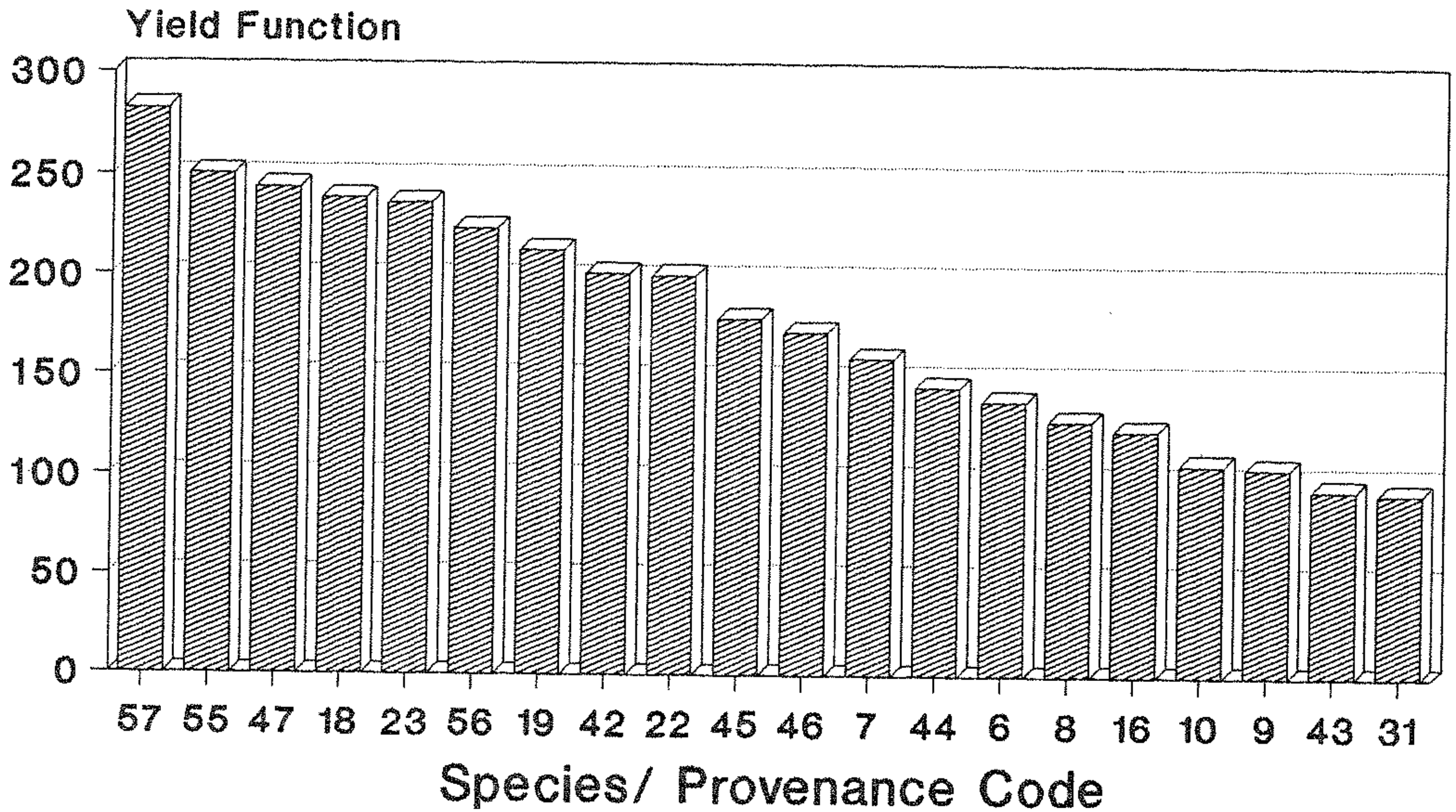


FIGURE 5

THABA PUTSOA

95 Percent Confidence

Intervals for Factor Means

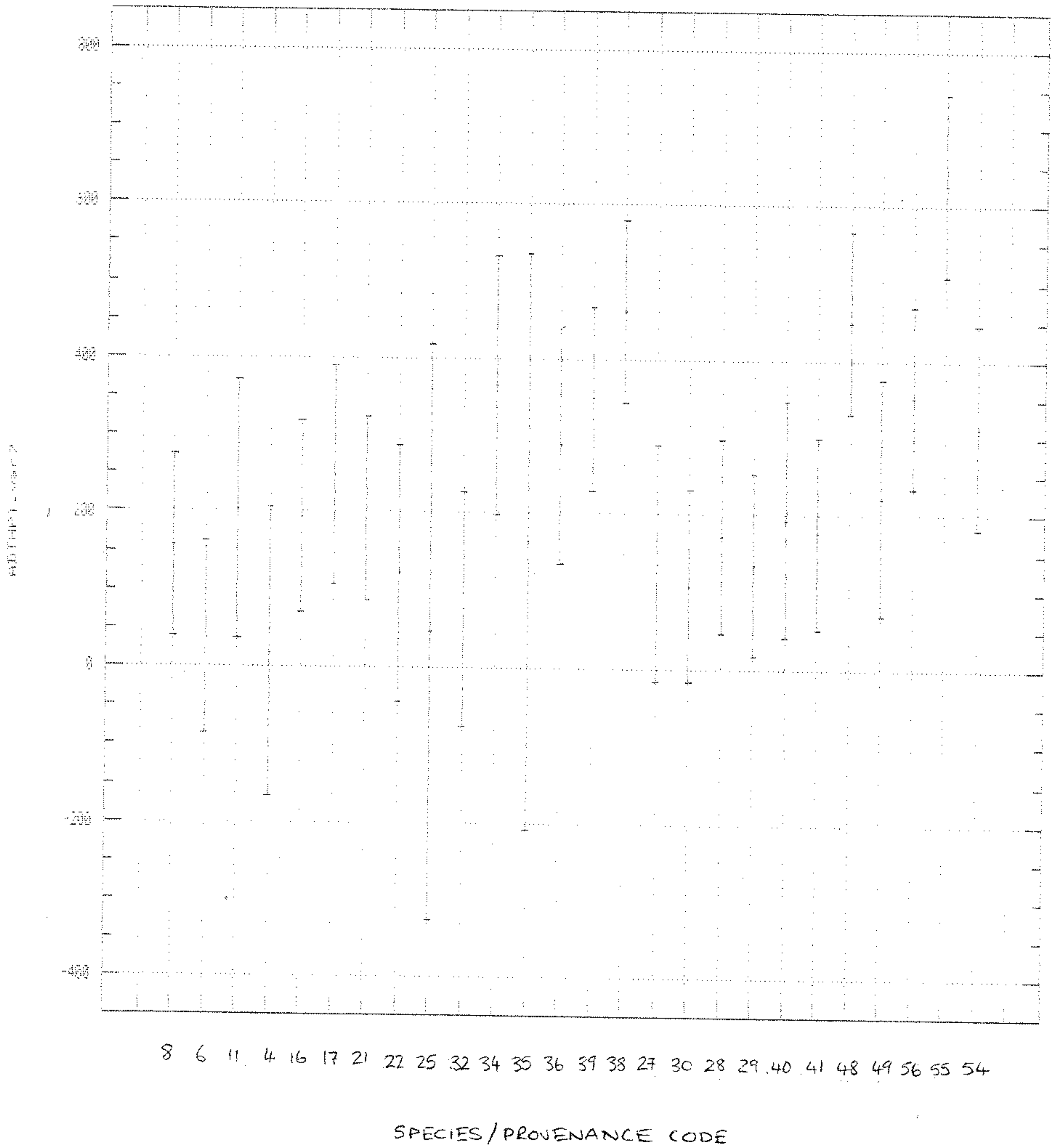


FIGURE 6

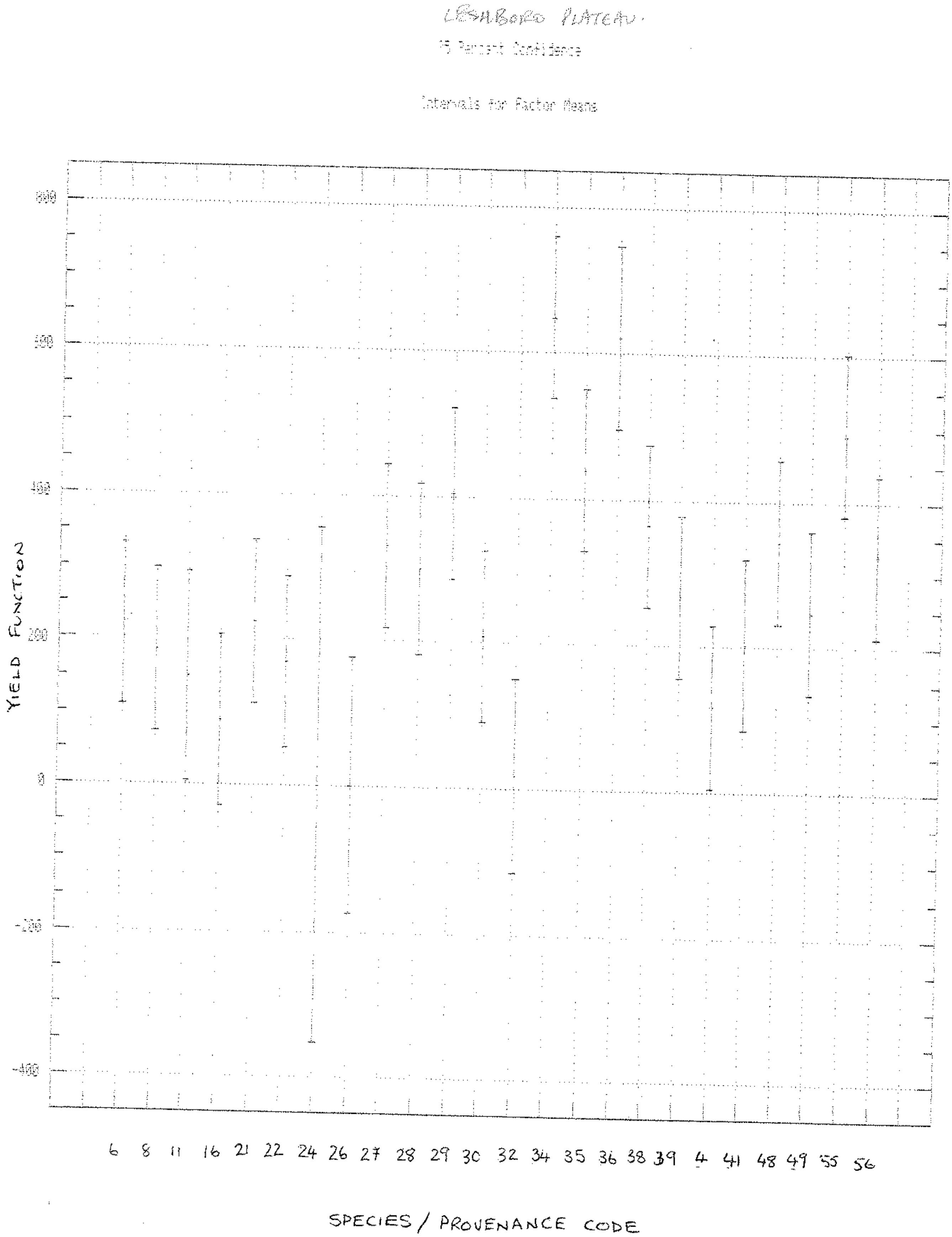

LESHBORO PLATEAU.
95 Percent Confidence
Intervals for Factor Means
800
600
400
200
0
-200
-400
YIELD FUNCTION
6 8 11 16 21 22 24 26 27 28 29 30 32 34 35 36 38 39 4 41 48 49 55 56
SPECIES / PROVENANCE CODE

Table 8 t-tests for Replicated Thaba Putsoa Trial

Comparison of mean heights with best performing seedlot

Code	x1	x2	x1-x2	root s2/n1	root s2/n2	df	t	signif?
38	2.525	2.458	0.067	0.0855	0.0855	18	0.391813	ns
48	2.525	2.456	0.069	0.0855	0.0855	18	0.403509	ns
56	2.525	2.44	0.085	0.0855	0.0855	18	0.497076	ns
39	2.525	2.396	0.129	0.0855	0.0855	18	0.754386	ns
54	2.525	2.432	0.093	0.0855	0.0956	16	0.513528	ns
21	2.525	2.434	0.091	0.0855	0.0855	18	0.532164	ns
34	2.525	2.673	-0.148	0.0855	0.121	13	-0.71671	ns
41	2.525	2.297	0.228	0.0855	0.0917	17	1.286682	ns
33	2.525	2.568	-0.043	0.0855	0.1104	14	-0.2195	ns
28	2.525	2.275	0.25	0.0855	0.0956	17	1.380453	ns
17	2.525	2.307	0.218	0.0855	0.1022	15	1.161428	ns
16	2.525	2.204	0.321	0.0855	0.0902	17	1.826978	P< 0.1
40	2.525	2.431	0.094	0.0855	0.1104	14	0.479837	ns
41	2.525	2.297	0.228	0.0855	0.0902	17	1.297666	ns
8	2.525	2.108	0.417	0.0855	0.121	18	2.01937	P< 0.1
49	2.525	2.349	0.176	0.0855	0.1104	14	0.898418	ns
30	2.525	2.175	0.35	0.0855	0.0902	17	1.992032	P< 0.1
22	2.525	2.341	0.184	0.0855	0.121	13	0.891041	ns
11	2.525	2.37	0.155	0.0855	0.121	13	0.750605	ns
27	2.525	2.191	0.334	0.0855	0.1104	14	1.704952	ns
6	2.525	1.805	0.72	0.0855	0.0902	17	4.097894	P< 0.001
35	2.525	2.646	-0.121	0.0855	0.2705	9	-0.33989	ns
4	2.525	1.817	0.708	0.0855	0.13526	12	3.207103	P< 0.01
32	2.525	1.474	1.051	0.0855	0.121	13	5.089588	P< 0.001
25	2.525	2.001	0.524	0.0855	0.2705	9	1.47191	ns
24	2.525	NO SURVIVORS		0.0855	NO SURVIVORS			
26	2.525	NO SURVIVORS		0.0855	No SURVIVORS			

Table 9 t tests for Leshoboro Plateau

Comparison of mean heights with best performing seedlot

Code	x1	x2	x1-x2	root s2/n1	root s2/n2	df	t	signif?
36	2.659	2.695	-0.036	0.068	0.076	16	-0.25	ns
55	2.659	2.6	0.059	0.068	0.068	18	0.433824	ns
35	2.659	2.693	-0.034	0.068	0.068	18	-0.25	ns
27	2.659	2.573	0.086	0.068	0.068	18	0.632353	ns
29	2.659	2.598	0.061	0.068	0.0717	17	0.43665	ns
38	2.659	2.512	0.147	0.068	0.068	18	1.080882	ns
56	2.659	2.527	0.132	0.068	0.068	18	0.970588	ns
48	2.659	2.602	0.057	0.068	0.068	18	0.419118	ns
28	2.659	2.553	0.106	0.068	0.0717	17	0.758769	ns
32	2.659	1.731	0.928	0.068	0.0812	15	6.219839	P< 0.001
39	2.659	2.455	0.204	0.068	0.068	18	1.5	ns
6	2.659	2.46	0.199	0.068	0.068	18	1.463235	ns
30	2.659	2.512	0.147	0.068	0.0717	17	1.052255	ns
41	2.659	2.556	0.103	0.068	0.0717	17	0.737294	ns
8	2.659	2.408	0.251	0.068	0.068	18	1.845588	P< 0.1
21	2.659	2.394	0.265	0.068	0.068	18	1.948529	P< 0.1
4	2.659	2.267	0.392	0.068	0.068	18	2.882353	P< 0.01
22	2.659	2.528	0.131	0.068	0.0717	17	0.937724	ns
11	2.659	2.512	0.147	0.068	0.0878	14	0.943517	ns
16	2.659	2.153	0.506	0.068	0.0717	17	3.622047	P< 0.01
32	2.659	1.731	0.928	0.068	0.0812	15	6.219839	P< 0.001
26	2.659	1.219	1.44	0.068	0.1074	12	8.209806	P< 0.001
24	2.659	1.609	1.05	0.068	0.215	9	3.710247	P< 0.01

Results of Form Assessment

Results are shown in Table13. Several seedlots tend to produce multiple stems, such as E. camphora, E. neglecta and E. stellulata. E. camphora and E. stellulata reach tree sized proportions, whereas E. neglecta grows only into a large bush. Others generally produce single stems, such as E. macarthurii and E. nova-anglica.

Species to be considered for pole production, because of particularly straight stems comprise: E. dalrympleana; some seedlots of E. glaucescens (13273) and (13287); two seedlots of E. macarthurii (11821) and (12023); two seedlots of E. nitens (11861) and (12102), both seedlots of E. nova-anglica; two seedlots of E. rubida (11290) and (11866); and four seedlots of E. viminalis (10073), (10811), (11175) and (11743).

For rough poles for construction of traditional houses many of the other species could be considered. Seedlots of three species are entirely unsuitable: E. neglecta because of the small stems and E. camphora (11938) and E. perriniana (10840) and (12027) because the stems are too crooked.

Some species, it appears grow rather differently in Lesotho than in their natural habitat. The growth of the E. stellulata seedlots were thought to be more tree-like than the bushy growth found in its natural range (Lavery, pers. comm.).

Results of MAIs

These trials have yielded seedlots that will grow faster than material the FD is using at present. The average MAI for eucalypts in Lesotho is 8.

At Leshoboro Plateau the best seedlot was the E. nitens seedlot from Badja Mts New South Wales, with an MAI of 22. Other E. nitens seedlots performed admirably. Another seedlot with excellent growth rate was E. stellulata, from Nimmitabel, NSW.

Direct comparison between the Ha Ntsane results and those of other trials is difficult owing to the different ages. MAIs for the same seedlots are noticably lower than those from Leshoboro Plateau. It is likely that at the same age as the Leshoboro trial the MAIs will be considerably greater as the sites are similar. The results appear to show that if volume production was the main criteria for rotation length then a rotation of over 9 years, the age of the Ha Ntsane trial is desirable. Again E. stellulata had grown rapidly, with the best seedlot having an MAI of 13. Other species with respectable MAIs were E. rubida, E. glaucescens, E. gunnii and one seedlot of E. pauciflora ssp. debeuzevillei.

The MAIs in the upland trials at Thaba Putsoa are generally lower, with the exception of a few seedlots at the replicated trial, such as E. stellulata, from Nimmitabel, NSW (MAI of 20) and E. nova-anglica from Ebor, NSW (MAI of 16). This reflects the more severe climate.

TABLE 10 RESULTS OF FORM ASSESSMENT

Stem Straightness: 1=straight 2=slightly crooked 3=very crooked
Branching intensity: 1=heavily branched - 3=lightly branched

Forking expressed as a % of the trees as
Branch thickness: 1=thin - 3=thick

Species	Seedlot	Stem	% Forking low	% Forking high	% Forking both	OPEN branching intensity	OPEN branch thickness	CLOSED branching intensity	CLOSED branch thickness	TRIAL
E. badjensis	12090			No survivors						
E. blakelyi	11819			No survivors						
	11835			No survivors						
E. bridgesiana	M. Hoek	1.67	0	70		1	1	2	1	L/25/6
	M. Hoek	1.8	9	0	0	1.3	1	1	1	L/25/7
E. camphora	9839		Too small to assess form							L/25/27
	11938	2.4	32	0	0	1.43	1	None	None	L/25/6
	11938	2	42	0	0	3	1	None	None	L/25/6
	11938	1.25	71	0	6	1	1	1	1	L/25/97
	11938	1.7	45	3	0	1	1.6	1	1.2	L/25/7
	12447	2	82	0	2	1	1	1	1	L/25/97
	12448	2	40	0	0	2.75	1.7	3	1	L/25/6
	12448	2	54	14	0	1.7	1	1	1	L/25/97
	12448	1.9	76	0	0	2	1.8	1.6	2	L/25/7
	12634	1.5	59	3	0	1	1.5	1	1	L/25/97
	12315	2	57	0	7	1	1	1	1	L/25/97
E. chapmaniana	12304	1.3	17	0	0	2	1	2	2	L/25/6
	12304	1.3	27	0	0	1.3	1.3	1.3	1.3	L/25/7
E. dalrympleana	9537	1	16	0	0	1	2	None	None	L/25/27
	11721	1	37	0	0	2	1	None	None	L/25/27
	12097	1	57	0	0	1	1	None	None	L/25/27
E. deanei	11245		No survivors							
E. glaucescens	10841	2	54	0	0	2.16	1.33	2.5	1.5	L/25/6
	10841	2	38	0	0	None	None	2	1	L/25/7
	10841	2	62	0	14	3	2	2	2	L/25/97
	10841	2.2	64	0	0	3	1.2	2.8	1.2	L/25/7
	11253	1.9	20	0	0	2.5	2.3	2.7	2	L/25/6
	11253	2	77	0	0	1	1	None	None	L/25/27
	13273	1	54	5	0	1	1	3	1	L/25/97
	13287	1	59	5	0	3	1	3	1	L/25/97
E. gunnii	11977	1	0	9	0	3	1	None	None	L/25/27
	12583	1.6	23	18	0	2	1.37	2	1	L/25/6
	12583	2	66	3	0	2.2	1.5	3	1	L/25/7
	12864	1.8	13	0	0	2	1	None	None	L/25/6
	12864	2	43	4	11	3	1	3	1	L/25/97
	12864	2.1	21	8	0	2.9	1.1	3	1	L/25/7
	12956	1.5	35	10	35	3	1	2	1	L/25/97
E. laevopinea	C747		No survivors							L/25/6
	11653		No survivors							L/25/6
	11653	2	0	0	0	3	1	None	None	L/25/7
E. largiflorens	8646		No survivors							L/25/6
	8646		Few survivors too small to assess							
E. macarthurii	10942	1.4	31	15	0	2	1	1	1	L/25/6
	10942	1.1	19	6	3	3	2.3	3	1.7	L/25/7
	11821	1.4	12	12	0	1.5	1.7	1.7	1.3	L/25/6
	11821	1	0	0	0	2	2	None	None	L/25/27
	11821	1.4	30	3	0	3	1.33	3	1.55	L/25/7
	12023	1.1	30	0	0	1.9	1.3	1	1	L/25/6
	12023	1	23	0	0	3	2	None	None	L/25/27
	12023	1.2	30	13	3	2.8	1	2.8	1.6	L/25/7
	30946	1.3	29	0	0	2.3	1.5	2.5	1	L/25/6
	30946	1.3	11	24	3	2.8	1.7	3	1	L/25/7
E. melliodora	28784	2	27	8	0	1	1	2	1	L/25/97
E. neglecta	7339	2	100	0	0	3	1	None	None	L/25/6
	7339	2	100	0	0	3	1	0	0	L/25/7

TABLE 10 CONTINUED

Stem Straightness: 1=straight 2=slightly crooked 3=very crooked
Branching intensity: 1=heavily branched - 3=lightly branched
Forking expressed as a % of the trees as
Branch thickness: 1=thin - 3=thick

Species	Seedlot	Stem	% Forking low	% Forking high	% Forking both	OPEN branching intensity	OPEN branch thickness	CLOSED branching intensity	CLOSED branch thickness	TRIAL
E. nitens	11814		Clumped with other seedlots at L/25/27							
	11861	1	0	0	0	3	3	2.8	2.8	L/25/6
	11861	1.1	14	0	0	3	2	3	2.6	L/25/7
	12102	1	0	0	0	2	2	None	None	L/25/6
	12102	1	12	0	0	2.3	1.8	2	1.7	L/25/7
	12107	1.4	36	0	0	2.8	2	3	2.3	L/25/7
	12107	1	9	0	0	2.4	2	3	3	L/25/6
	12155		Clumped with other seedlots at L/25/27							
	clumped	1	50	0	0	3	3	3	3	L/25/27
E. nova-anglica	10717	1	18	5	0	1.4	1.3	1	1	L/25/6
	10717	1	50	0	0	1	2	None	None	L/25/27
	10717	1.3	7	19	2	1	1	1.7	1.8	L/25/7
	11667	1.1	9	11.3	3	1.8	1.5	1.2	1.5	L/25/6
	11667	1.2	14	17	2	1.4	1.4	1.2	1.2	L/25/7
E. pauciflora	10808	2	31	13	0	1.4	1	1	1	L/25/6
	12009	1.3	6	0	6	1	1	1	1	L/25/6
	12009	2	40	0	0	1	1	None	None	L/25/27
	12009	1.3	63	0	0	1.1	1.3	1	1	L/25/7
E. debeuzevillei	8777	1.3	74	3	15	1.8	1.5	None	None	L/25/97
	9829	1.7	89	0	11	2	1	1	1	L/25/97
E. perriniana	10840	2.8	43	5	19	None	None	2.2	1	L/25/97
	12027	2.8	67	0	12	1.5	1.5	1.5	1.5	L/25/97
	12442	1.5	69	6	0	None	None	3	1	L/25/97
E. rubida	11290	1	23	0	0	1	1	1	1.3	L/25/97
	11866	1	15	3	0	1	1.5	1	1.6	L/25/7
	11866	1.2	12	0	4	1.3	1	1	1.7	L/25/6
	12438	1.2	27	0	0	2.2	1.4	1	1	L/25/6
	12438	1.3	9	3	0	1.8	1.5	1.5	1.5	L/25/7
	28796	1.4	3	24	5	1	2	1	2	L/25/7
	M' Hoek	2	33	16	0	2	3	None	None	L/25/27
E. sideroxylon	12017		No survivors							
	11844		No survivors							
E. stellulata	10443	2.1	52	17	0	1.1	1.3	1	1	L/25/6
	10443	2	0	0	25	1	2	None	None	L/25/27
	11287	2	66	0	20	1.1	1	1	1	L/25/6
	11287	2	75	0	0	1	3	None	None	L/25/27
	11287	2	78	0	19	1	1	1	1	L/25/97
	11287	1.8	92	0	0	1	1.3	1.5	1	L/25/7
	12293	2	56	6	6	1.3	1.7	1	1.2	L/25/6
	12293	2	58	4	36	1	1	1	1	L/25/97
	12293	1.9	97	0	0	1.4	1.3	1.3	1	L/25/7
	12987	1.8	49	4	47	2	1	1	1	L/25/97
E. viminalis	10073	1	0	0	0	3	1	None	None	L/25/27
	10811	1	0	0	0	2	2	None	None	L/25/27
	11175	1	0	0	0	1	2	None	None	L/25/27
	11743	1	0	0	0	3	3	None	None	L/25/27
	12282	2	0	0	0	1	1	None	None	L/25/27

DISCUSSION

Assessment of the performance of species or subspecies in the Trials

Survival after the first winter

Thaba Putsoa

After the first winter four species were found to have particularly high mortality in the replicated trial; E. chapmaniana, E. laevopinea, E. largiflorens and E. nitens (Richardson, 1985). These were attributed mainly to cold.

Of the other species one seedlot of E. rubida (12438) had high mortality yet another (12009) had low mortality.

At the unreplicated trial planted the previous year, E. badjensis, E. blakelyi, E. pauciflora ssp. debeuzevillei, E. nitens, E. sideroxylon, E. deanei and some seedlots of E. viminalis showed poor survival after the first winter. The 10073 Tasmanian seedlot showed good survival of approximately 75%. Of the others E. camphora also showed poor survival but it was noted that it had been poorly planted. The death in the following species may largely be attributed to cold: E. sideroxylon, which is known as a drought-hardy species; E. blakelyi which showed good survival over its first two winters at a further replicated trial at Leshoboro planted in 1980, E. nitens, which had high mortality the following year at the replicated trial and yet low mortality at Leshoboro Plateau.

Ha Ntsane

At Ha Ntsane the species with the highest mortality after the first winter was E. pauciflora ssp. debeuzevillei. Generally survival of other species was good, with average survival in the trial of 71%.

Leshoboro Plateau

At Leshoboro Plateau mortality was highest for E. chapmaniana, E. laevopinea, E. largiflorens and E. neglecta. Most other species showed little mortality despite a five month long dry period from April (Richardson, 1985).

As E. neglecta had survived at the high altitude Thaba Putsoa site it was thought that drought not cold was the main factor responsible for the mortality (Richardson, 1985).

Growth and Survival by Autumn 1991

E. badjensis

At the unreplicated trial at Thaba Putsoa, the only one in which this species was planted no trees survived. This species is not recommended for planting or further work.

E. *blakelyi*

This species is recorded as tolerating light to moderate frosts and is slow growing initially (Poynton, 1979).None of the twenty trees planted at the unreplicated site at Thaba Putsoa have survived. Survival of two seedlots at a closed trial at Leshoboro Plateau was reasonable at 54% and 67% but growth was very poor at 62 months old. No further work will be undertaken on this species.

E. *bridgesiana*

This species has been planted widely in Lesotho and is known for its drought tolerance. Although recommended by Pryor, (1973) its growth is not particularly fast or the stems straight, and the wood, although dense has a reputation for sparking, making it unsuitable for open fires. Richardson and Meakins, (1986) describe this species as being susceptible to damage by Eucalyptus Snout Beetle. At both the replicated Thaba Putsoa trial and at Leshoboro Plateau the survival was good but growth very poor. The results from this assessment agree with Richardson´s, (1985) findings and this species should no longer be used in plantations in Lesotho.

E. *camphora*

In the two lowland sites at Ha Ntsane and Leshoboro Plateau, this species showed good survival but poor growth and unexceptional to poor stem form. Richardson, (1985) describes the species as having fast early growth, which slowed down at the end of its second year. He also described the species as being susceptible to Eucalyptus Snout Beetle, confirmed in observations during the latest assessment. At no trial did E. *camphora* grow particularly well. This species is not recommended for planting in Lesotho.

E. *chapmaniana*

At both the lowland Leshoboro Plateau trial and the mountain site at Thaba Putsoa this species has showed poor growth and survival and should not be established in plantations in Lesotho.

E. *dalrympleana*

At the unreplicated trial at Thaba Putsoa, two seedlots of this species have performed particularly well the Wiharega (11721) seedlot from Tasmania and the Cotter Hut Area (12097) from ACT. These seedlots are therefore recommended for mountain plantings.

At a closed trial at Leshoboro Plateau, a NSW seedlot of E. *dalrympleana* from Coree Flats (12512) had best overall performance out of 40 seedlots of 17 species. It can be recommended for a small trial planting in the lowlands.

E. *deanei*

Most individuals of this species had died at the unreplicated Thaba Putsoa site. Survival was only 15% a year after planting and 5% in 1991. The surviving trees at Thaba Putsoa, showed much evidence of damage by Eucalyptus Snout Beetle, although otherwise appeared healthy. This species is not hardy enough for sheltered mountain conditions in Lesotho. At a closed trial at Leshoboro Plateau three seedlots varied in survival between 48% and 80%, although growth was poor. This species should not be considered for planting in Lesotho.

Trials in the Transvaal in South Africa, have found it to be both susceptible to frost damage and to be slow growing (Schonau and Gardner, 1991).

E. glaucescens

This species has shown good survival at Thaba Putsoa and adequate survival at Lshoboro Plateau, although growth has not been particularly fast at either site. At Ha Ntsane two seedlots Mt. St. Gwinear (13273) from Victoria and Guthega Koscuisco (13287) from NSW showed good growth and reasonable survival of 73% and 61% respectively.

E. gunnii

The Lesotho trials show E. gunnii to be hardy but fairly slow growing. In natural forest, rather than natural open woodland it grows as a large straight tree (Orme, 1983).

At the replicated Thaba Putsoa trial one seedlot from Steppes, Tasmania (12583) has grown and survived better than the other from Miena Central (12864), Tasmania. At the unreplicated trial a further seedlot from Shannon, Tasmania (11977) has grown and survived well and has produced particularly straight, if heavily branched individuals. Limited test plantings in the mountains should be established to test its growth and survival on harsher sites than Thaba Putsoa.

Orme, (1983) believes that E. gunnii shows most promise as a source of frost-resistant genes for hybridisation programmes with faster growing but less hardy species, such as E. nitens and E. dalrympleana For E. nitens Orme suggests two ways in which the hybrid may be better than E. nitens: in increased cold-tolerance and in better coppicing ability. In Lesotho however E. nitens coppices well, although most areas are still in their first rotation.

E. laevopinea

At both the replicated Thaba Putsoa site and the site at Leshoboro this species had failed.

E. largiflorens

One seedlot of this species was tested at Leshoboro Plateau and the replicated trial at Thaba Putsoa. At both sites its performance was unsatisfactory and no further work will be undertaken.

E. macarthurii

Although planted extensively on frosty areas in South Africa it has not grown particularly well at the two Thaba Putsoa trials or at Leshoboro Plateau. Results from this assessment show that the South African seedlot is certainly not the best for either lowland or mountain conditions in Lesotho. Of the three Australian seedlots, one from Bowral, ACT (10942) performed best in the lowlands and one from Marulan, NSW (12023) worst, while in the mountains the order was reversed. It showed reasonable performance in the lowlands and the Bowral seedlot should be considered for future lowland plantations.

Although Eucalyptus Snout Beetle attack of E. macarthurii in Lesotho was not mentioned in Richardson and Meaklins, (1986) this species has for some time had light damage by this insect.

In a trial in the Transvaal of moderately cold-tolerant eucalypts, including E. nitens and E. viminalis this species was found to be most frost resistant (Schonau and Gardner, 1991).

E. melliodora

One South African seedlot of this species was planted at Ha Ntsane. The stems were fairly straight and branching light, survival was reasonable at 64%, however height and diameter growth were poor. Although Pryor, (1973) recommends this species should be planted below 1700m our results suggest there are other species with better growth. It is not recommended for plantations in Lesotho.

E. neglecta

This species grows into a multistemmed shrub, all stems being very small in diameter. Survival is reasonable at both the Leshoboro Trial (61%) and the replicated Thaba Putsoa (58%) Trial but because of its growth habit this species will not be considered for planting.

E. nitens

This is a very fast growing species, on lowland and foothill sites. Poor survival excludes it from mountain plantings, although those individuals that have survived show good growth. All seedlots exhibit straight stems but heavy branching.

At Leshoboro Plateau two of the E. nitens seedlots from Nojee, Victoria (12102) and Mount St Gwinear, Victoria (12107) have grown and survived particularly well. These provenances can be recommended for planting in the lowlands and foothills. The seedlot from Badja Mount (11861) in NSW also showed excellent growth, being marginally inferior to the other two. However survival of the NSW provenance was slightly greater. South African experience has shown NSW seedlots to be more frost resistant than those from Victoria (Nixon, 1983).

At the unreplicated trial at Thaba Putsoa 90% of the E. nitens had died and the identity of the remaining trees could not be ascertained. All surviving trees were assessed as mixed E. nitens. Those few trees that did survive have grown exceptionally fast, the largest having a dbh of 40.2cm and a height of 13.2m at age 145 months.

Similarly at the replicated trial at Thaba Putsoa most trees died but those that survived have grown very quickly. Of the three seedlots the Badja Mountain (11861) NSW and Mt St Gwinear (12107) Victoria performed similarly although the Nojee, (12102) Victoria performed particularly badly with only 2% surviving. Survival of any seedlot did not exceed 25%.

This year there have been several reports of Eucalyptus Snout Beetle attacking coppice and first rotation crops of E. nitens at Molumong Plateau and the situation is being monitored. To date the damage has been minor and was probably due to drought stress resulting from a prolonged dry period in early summer 1990-91. A similar outbreak on E. nitens occurred in spring 1983 and was attributed to severe drought conditions as the damage declined in following years (Richardson and Meakins, 1986).

This species is one of the most productive eucalypts in Lesotho and should be planted more extensively, on the more moist sites in the lowlands or in the foothills, where higher rainfall occurs. As the seedlot from Nojee has performed well at Leshoboro but abysmally at the replicated trial at Thaba Putsoa. This suggests it may be particularly susceptible to frost and not suitable for planting in the high foothills. Unfortunately without a trial in the foothills it is difficult to make concrete recommendations.

E. nova-anglica

This species shows much promise, particularly for sheltered mountains sites and in the foothills. One seedlot from Ebor Area (10717), NSW has shown particularly good performance at the replicated Thaba Putsoa trial. This, and the other seedlot from SW Walcha (11667), NSW tested at this trial have particularly good form and light branching and would make good poles. In the lowland trial at Leshoboro Plateau other species showed faster growth and so planting of this species should be confined to foothill and sheltered mountain sites.

E. pauciflora

Generally trees of this species are multi-stemmed, with few fine branches. Although Pryor, (1973) felt this species showed potential it did not perform well in any of the three trials where it was tested.

This is noted as a very frost-resistant species (Harwood, 1983) and at the unreplicated trial at Thaba Putsoa 70% of the trees have survived. However at the replicated trial and at Leshoboro Plateau survival has been poor. During the drought early in summer 1990-91 many trees were badly drought stressed, the foliage browned and withered and it may be that drought has been the main reason for this mortality.

E. pauciflora ssp debeuzevillei

This species tends to be multistemmed, with fairly straight, thin stems and light branching. At Ha Ntsane one seedlot, the Jounama Peak (8777), NSW has performed better than the other, the Mt Ginini (9829), NSW. However its growth has not been fast enough to merit planting on a large scale in the lowlands and foothills. At the unreplicated Thaba Putsoa site growth and survival was poor and so this species is not recommended for planting in the high foothills or mountains.

E. perriniana

This species was only planted at Ha Ntsane. Three seedlots were represented in the trial and none have grown particularly quickly and all have poor form. No planting of this species is recommended.

E. rubida

This is the most planted eucalypt in Lesotho and five seedlots were tested in the four trials. Unfortunately, direct comparison between locally collected material and imported seedlots is not possible as the local seedlot is only found at the unreplicated trial at Thaba Putsoa. No imported seedlots were included.

Of the two imported seedlots at the replicated Thaba Putsoa trial both showed very good growth but the (11866) seedlot gave considerably better survival.

At the unreplicated trial at Thaba Putsoa a local seedlot wastested, but no other seedlots of E. rubida were tested. Growth generally at the unreplicated trial has been poor compared with the replicated trial so comparisons between them are not valid.

Three seedlots were tested at Leshoboro Plateau. At this site a South African seedlot (28796) from Belfast, Transvaal performed better than the Captains Flat (11866) seedlot, although the differences were not significant.

At Ha Ntsane a E. rubida seedlot from Oberon District, NSW (11290) showed excellent performance and yielded straight stems with light branching. Unfortunately direct comparison with locally collected material and the other seedlots is not possible as they were not included in the trial. However in a trial at Hleoheng comparison of this seedlot with a locally collected seedlot showed similar growth and survival.

Unfortunately it is still not possible to make recommendations about which seedlots of E. rubida should be planted.

E. sideroxylon

Two seedlots of this species were planted at the unreplicated trial at Thaba Putsoa. No trees had survived.

However, in plantations in the lowlands this species has shown good drought and frost tolerance and the species was recommended by Pryor, (1973) and was widely planted until it developed a reputation for suppressing ground vegetation (Poynton, 1986). Unfortunately two seedlots tested in two 1980 trials at Leshoboro and Tsikoane Plateaux showed very poor growth, although survival was good. This species cannot be recommended.

E. stellulata

In agreement with Richardson's (1985) results this is a promising species, with good survival and growth, in the lowlands and mountains. Found to be very frost-resistant, even more so than E. pauciflora (Harwood, 1983). It tends to produce several fairly straight stems, and is therefore a particularly good species to meet the rural market for rough poles and fuelwood. Furthermore it is noted as being a particularly good fuelwood, burning even when green (Poynton, 1979) It performance at all trials has been good and this adaptability to a wide range of sites makes it useful. It is therefore recommended.

At the replicated trial at Thaba Putsoa two seedlots, the Nimmitabel, NSW (11287) and the Gudgenby Area, ACT (12293) performed significantly better than the other from Oberon District, NSW (10443). The poor figures for dhh, height and survival at the unreplicated site can be explained. Accidentally many of the trees were cut and the smallest stems left. To obtain a rough estimate of the growth of this species at the trial the number of stumps and stems for each tree were assessed and any remaining stems measured. The average dbh of the remaining stems was multiplied by the original number of stems, before they were cut. As both the seedlots in the unreplicated trial were also tested in the replicated trial the results from the replicated trial will be used.

At Ha Ntsane the two NSW seedlots performed better than one from ACT. The best seedlot was that from Jerangle in NSW (12987) followed by one from Nimmitabel, NSW (11287). At Leshoboro the inferiority of the ACT seedlot compared with that from Nimmitabel, NSW was confirmed.

For lowlands, foothills and sheltered mountain sites the NSW seedlot from Nimmitabel (11287) is recommended. It has shown itself to be adaptable, performing well at Thaba Putsoa, Leshoboro Plateau and Ha Ntsane.

E. viminalis

This species was planted extensively in Lesotho but unfortunately, some provenances were found to be particularly susceptible to Eucalyptus Snout Beetle. This was noted as early as 1973 in Pryor's report. However there is a considerable amount of variation in susceptibility between and within provenances. In a study by Richardson and Meakins, (1986) a good correlation was found between the susceptibility of a particular seedlot and the latitude it originated from (Figure 7). Also morphology was found to have an influence on the susceptibility and damage, with trees with narrower leaves being more seriously damaged. Seedlots from NSW were most badly damaged, followed by Victoria and ACT.

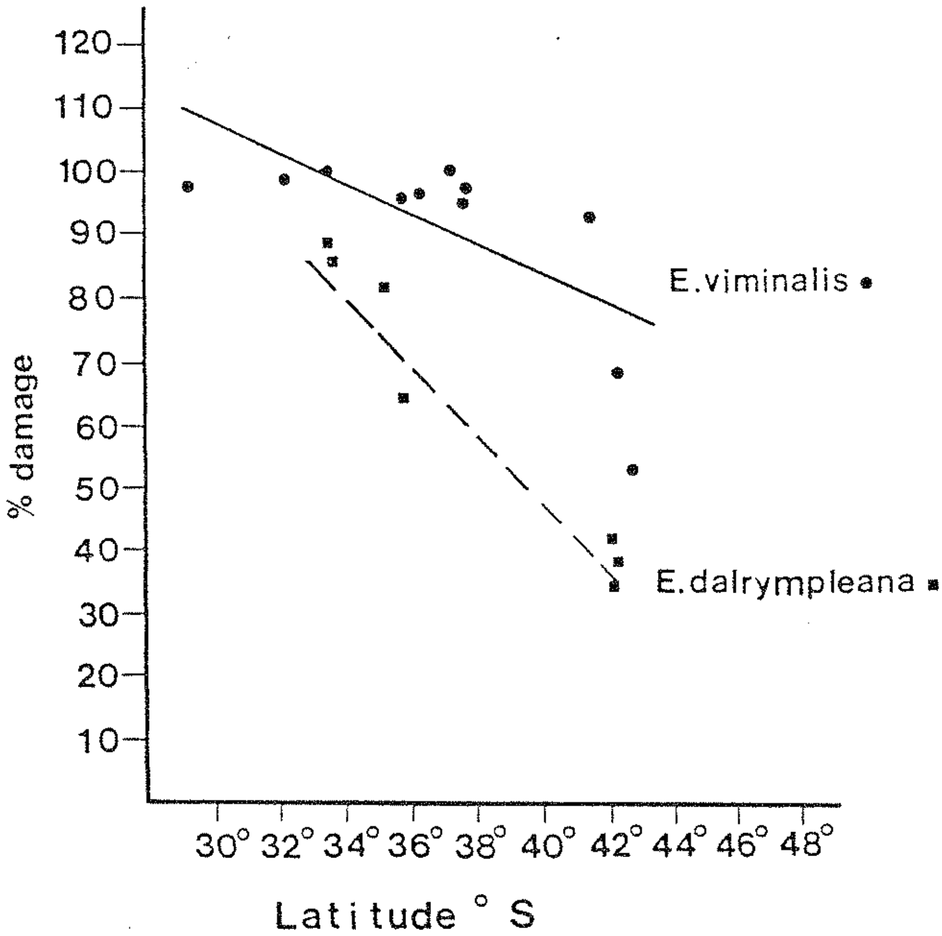


FIGURE 7. Comparison of Gonipterus *damage estimates on* Eucalyptus viminalis *(•) and* E. dalrympleana *(▪) with latitude of seed origin.* (Richardson and Meakins, 1986).

with Tasmanian provenances most resistant. The Swansea Tasmanian seedlot (10073) has performed exceptionally well at the unreplicated Thaba Putsoa trial and is recommended for planting in sheltered mountain and high foothill sites.

Pryor, (1973) recommends this species for planting above 6 000 feet (1 800m), where damage by snout beetle is less due to the harsher climatic conditions.

The less susceptible Tasmanian seedlots of E. viminalis are recommended for planting on sheltered mountain sites, particularly the Swansea seedlot (10073) which performed very well at the unreplicated Thaba Putsoa trial.

Other Eucalypts Trials in Lesotho

In addition to the four trials described, a further nine trials were established by the LWP or the FD between 1979 and 1989.

In 1979 a small trial (L/25/26) of simple design was planted at Ha Teko (1600m). After a year the only species vaguely healthy was E. sideroxylon (Richardson, 1980). At three years old E. glaucescens showed best height growth at 2.27m and the performance of E. sideroxylon was poor. None of the seedlots performed well, although the site was never fertilised. The poor growth of E. nitens and E. blakelyi were largely attributed to the dryness of the site (Richardson, 1980).

Two trials, both testing a similar range of seedlots were established in 1980 at Tsikoane (1800m), (L/25/9) and Leshoboro Plateux (L/25/8). Of the 39 seedlots three seedlots of E. dalrympleana showed much potential. Seedlots of E. blaxlandii, E. elata and E. radiata performed well at Tsikoane, but poorly at Leshoboro. Tsikoane receives slightly more rainfall, which may explain the differences.

In the same year a further trial (L/25/48) was established at Tsikoane testing eight species, each represented by a single seedlot. The identity of the seedlots of E. viminalis and E. badjensis is uncertain. Best survival was from a seedlot of E. blakelyi, whilst best growth was E. nitens. The E. nitens had a survival of 65%, a mean dbh of 16.9cm and a mean height of 11.2m after six and a half years. Of the others the E. macarthurii showed better survival at 91% but the dbh was two thirds that of the E. nitens. Other species either showed poor growth or poor survival.

A small trial also at Tsikoane (L/25/73) and planted a year later tested four species; E. fastigata, E. fraxinoides, E. smithii and a mixed seedlot of E. nitens. Both E. fastigata and E. fraxinoides performed almost as well as the mixed seedlot of E. nitens.

A trial (L/25/10) at Majapereng (1450m) planted in 1980 tested 25 seedlots covering 13 species. These were known to be less frost hardy and not surprisingly none of the seedlots showed good growth or survival.

At Hleoheng (1740m) a trial (L/25/110) was established in 1983 to compare a locally collected seedlot of E. rubida against an Australian seedlot. In addition nine seedlots covering seven other species were tested. At age 51 months the imported seedlot of E. rubida had not performed significantly better than the local one. Of the other species E. nitens, E. nortonii and E. youmannii showed good growth but poor survival and seedlots of the following species showed good growth and survival; E. regnans, E. stellulata and E. delegatensis. The poorest performer was E. badjensis. At a small trial planted at the same Forest Reserve in the same year eight (L/25/110a)seedlots of E. regnans all showed poor survival and one seedlot of E. ovata showed moderate survival and good growth.

In 1989 a trial (L/25/130) testing 59 seedlots, covering 19 species of Eucalypts was established at Molumong Plateau in the northern lowlands of Lesotho. Unfortunately during 1990 the trial was extensively damaged by herdboys, with atleast one of the three blocks being affected. Most of the leaders had been broken.

An additional eucalypt trial was established at Thaba Tseka (c. 2250m) in the mountains by Blair Orr. Sixteen species were tested; ten provenances of E. viminalis, three provenances of E. rubida, E. dalrympleana, E. pauciflora, E. camphora, E. aggregata, E. coccifera, E. fraxinoides, E. glaucescens, E. stellulata, E. gunnii, E. johnstonii, E. laevopinea, E. nitens, E. neglecta and E. parvifolia . None of them survived (Orr, 198? in Bazill, 1989) and Mr Orr felt eucalypts were not suitable for the area.

Natural Distribution of Cold-tolerant Eucalypts

Turnbull and Eldridge, (1983) described the natural environment of cold - tolerant eucalypts and recommend using information on natural habitat for matching species to site. Many of the species mentioned have been tested in Lesotho.

In its natural distribution in mainland Australia E. stellulata is common on frosty, poorly drained sites in mainland Australia. Associated species in Northern New South Wales include E. nova-anglica and E. camphora in Southern areas.

On better drained sites, on the edges of frost hollows E. ovata, E. pauciflora, E. rubida and E. viminalis are common. Along perennial streams E. neglecta is found. Near the tree line E. pauciflora is found, with subspecies debeuzevillei and niphophila occuring in Southern New South Wales. In the extreme conditions of the Australian Alps, E. glaucescens, occasionally with E. perriniana and E. moorei forms multi-stemmed thickets.

In Tasmania on frosty, temporarily waterlogged sites, E. perriniana is an occasional associate of E. rodwayii. Adjacent to these areas E. gunnii and E. pauciflora are found. The tree line mainly comprises two species, E. coccifera and E. subcrenulata. With decreasing altitude a small shrub, E. vernicosa gives way to E. subcrenulata which in turn is replaced with E. johnstonii. In the north-east E. gunnii is dominant. E. pauciflora is not atree line species in Tasmania but does form pure stands at below 1 000m altitude (Turnbull and Eldridge, 1983).

At a lower altitude, the montane forests contain most of the fast growing timber trees. These include E. delegatensis, E. fastigata, E. fraxinoides, various subspecies of E. globulus, E. obliqua, E. regnans, E. caliginosa, E. cypellocarpa, E. dalrympleana, E. nitens and E. viminalis. Of these species only E. nitens and E. delegatensis are considered for sites with severe frosts and where snow is common.

Species recommended in the literature

There are several summer rainfall areas with similar climatic conditions to Lesotho:

New Zealand

In New Zealand in cold, temperate areas four species are recommended. However the rainfall (between 750 and 2 000mm) is greater than that experienced over most of Lesotho. The species considered suitable for fuelwood are E. nitens and E. fastigata, (Anon, 1984) while for decorative timber E. regnans and E. delegatensis are recommended (Anon, 1976; Anon, 1984). Only E. fastigata is considered suitable for uses requiring strength and natural durability (Anon, 1984).

A study of E. fastigata by Wilcox, Rook and Holden (1980) showed that two New South Wales seedlots; Oberon (1220m) and Barringdon Tops (1430m) were most frost resistant. Of exotic seedlots Draycott (South Africa) and Kaingora (New Zealand) were most frost hardy. Both seedlots were collected from harsh sites where severe ground frosts occur.

Republic of South Africa

In the Republic of South Africa, considerable effort has been expended to find productive eucalypts to replace the most commonly planted species, E. grandis, on frosty sites. Ten species of frost-tolerant eucalypts successfully planted in South Africa and the area they cover were described in Van Wyk, (1983):

SPECIES	AREA (ha)	SPECIES	AREA (ha)
E. fastigata	30 978	E. fraxinoides	655
E. macarthurii	16 871	E. dunnii	342
E. elata	9 097	E. maidenii	140
E. nitens	7 194	E. rubida	70
E. smithii	900	E. deanei	20

Van Wyk, (1983) notes that E. nitens and E. fastigata are the most productive species. A New South Wales seedlot of E. nitens is used on the highveld, whereas the identity of the seedlots of E. fastigata is not known (Nixon, 1983).

Three trials each were established at three sites in Natal in 1979 by the Wattle Research Institute. Only one, at Epsom site experienced severe frost (-0.5 C to -3.2 C). At eleven months old, species that were shown to be frost resistant in their first winter were E. bridgesiana, E. dalrympleana, E. macarthurii and E. viminalis. Unusually, E. globulus ssp. maidenii was found to be susceptible to frost damage (Nixon, 1983). In Lesotho this subspecies was fairly frost resistant but is no longer planted because of its susceptibility to Eucalyptus Snout Beetle (Gonipterus scutellatus). E. viminalis was also planted in Lesotho and was also widely established in the Eastern Transvaal Highveld until it too was severely attacked by Eucalyptus Snout Beetle.

The trial also included E. nitens, unidentified seedlots of which have performed well in the foothills of Lesotho. Those provenances from New South Wales (Barringdon Tops and Ebor) were found to be most frost tolerant, whilst those from Victoria (Rubicon and Toorongo) were susceptible to frost damage (Nixon, 1983). Other authors have recommended E. nitens as being the most promising species for afforestation in the Eastern Transvaal highveld and Southeastern Transvaal (Purnell and Linquist, 1986). They cite results from various trials that suggest that New South Wales provenances give better performance in South Africa than those from Victoria (eg Darrow, 1980 in Darrow, 1983). In two trials in the Eastern Transvaal Highveld of twelve provenences of E. nitens differences between the seedlots were greater at the poorer of the two sites. Both sites showed the superiority of the New South Wales provenances in terms of dbh, height and volume (Purnell and Lindquist, 1986). With exceptions the NSW provenances showed better survival also. The poor performence of Victoria provenances may partly be due to greater infection by Mycosphaerella leaf disease (Purnell and Lindquist, 1986). In a later trial in the Eastern Transvaal those provenances from northern NSW were found to be more susceptible than those from southern NSW. A South African seedlot was found to be most resistant. These trials show however that there are Australian provenances with better growth than the South African seedlots (Stanger, 1990). The NSW provenances of E. nitens were also found to grow more quickly in trials in Zimbabwe (Quaile and Mullin, 1983). However densities of Victoria provenances were found to be higher that NSW provenances, excluding the Barrington Tops seedlot.

Unfortunately the cold-tolerant eucalypt most extensively planted in the East Transvaal Highveld, Eucalyptus fastigata is not represented in these four Lesotho trials. However, 56 month results of a trial at Tsikoane Plateau, in 1985 showed a seedlot of E. fastigata had attained a mean height of 8.05m and a survival of 79%. This compares with a mixed seedlot E. nitens which reached a mean height of 9.71m and a survival of 55%. In recent trials of E. fastigata conducted by ICFR the Southern NSW provenances performed better than those from Northern NSW. Data from other trials show that South African seedlots have much better form than those from Australia (Stanger, 1990).

Nepal

Above 1 500m in Nepal three eucalypt species were recommended by Jackson, (1987); E. saligna, E. grandis and E. globulus ssp. maidenii. The only one of these to have shown promise in Lesotho was E. globulus ssp. maidenii, which is attacked severely by

Eucalyptus Snout Beetle. E. *grandis* and E. *saligna* were not hardy enough for the climatic conditions in Lesotho.

Some winter rainfall areas have also yielded useful results on the frost tolerance of some of the eucalypts tested in the four trials.

United Kingdom

Following a particularly cold winter in 1981-82 a cold-hardiness classification of eucalypts tested in the UK was devised by Evans, (1983). Four divisions were proposed:

(i) Very hardy- likely to survive long cold periods of -10 to -14 C, or short periods of below -18.

(ii) Hardy- as above but not likely to survive below -16 C.

(iii) Moderately hardy- likely to survive long cold spells of -6 C to -9 C or short periods below -14 C.

(iv) Less hardy- likely to survive long cold periods down to -6 C or short periods down to -9 C.

In this classification E. *viminalis* and E. *macarthurii* are listed as being less hardy to frost. At Thaba Putsoa five seedlots of E. *viminalis* and four seedlots of E. *macarthurii* showed good survival. This is the most frosty of the three sites. The inclusion of E. *nitens* in this category is confirmed by the Thaba Putsoa trial where survival of this species was poor.

E. *stellulata* and E. *dalrympleana* are recorded as being moderately hardy, which contrasts with Harwood's (1983) results with E. *stellulata*. In Lesotho both species have shown good survival and reasonably fast growth at Thaba Putsoa. However, several plantations of E. *stellulata* in the mountains in Lesotho on exposed sites have failed.

Classed as hardy were E. *gunnii* from all origins except Central Tasmania and E. *glaucescens*. These have performed well at Thaba Putsoa and support this.

In the very hardy category E. *pauciflora* ssp. *debeuzevillei* was included, however the one seedlot at Thaba Putsoa has shown very poor survival. Results from Thaba Putsoa agree with central Tasmanian E. *gunnii* being classified as very hardy. One species that has shown good frost hardiness in the UK is E. *niphophila*. This was not included in the four Lesotho trials. Although it only grows to the size of a large bush; 6-9m tall it may be worth testing in Lesotho, where poles and fuelwood are the end products in the Government Forest Reserves.

The quality as poles, of some of the species that have performed well in these trials has been tested. Nixon, (1991) found that there was generally a high incidence of splitting for 13 species or subspecies of cold-tolerant eucalypts. Of those commonly planted by the FD, E. *nitens* was found to have a low level of extreme splitting and E. *macarthurii* a high level. Unfortunately,

E. rubida was not included in the trial.

CONCLUSIONS

The emphasis of the Forestry Division has moved away from Government planted woodlots towards supporting individuals and communities in their own tree planting efforts. Eucalypts have certain characteristics that make them suitable for inclusion into a community forestry programme:

(i) They will coppice, allowing produce to be harvested over several rotations before replanting is necessary. Thus, they can require only a low management input.

(ii) The coppicing ability also allows flexibility in the produce. Reduction of the coppice and varying the harvesting time can be used to influence the dimensions of the produce.

(iii) It is essential in a community forestry programme to adopt species that will perform well.Eucalypts have been grown in Lesotho for over 100 years and there is much information on the suitability of eucalypt species on a variety of sites. Nurseries are also familiar with propagating eucalypts.

The eucalypt most planted by the Forestry Division in Lesotho is E. rubida. This has proved to be frost-hardy and resistant to attacks by the Eucalyptus Snout Beetle. In the lowland trials it has shown good performance. Despite its inclusion in various trials there is no clear evidence that any of the imported seedlots are better than the local land race. Furthermore, one of the better Australian seedlots from Captains Flat, NSW has been used in plantations for some years and can be considered part of the Lesotho population. An improvement programme is planned by selecting plus trees from the 4, 000 ha planted.

Small areas of the E. glaucescens should be established in the lowlands. The seedlots that have performed well at Ha Ntsane; Mt St Gwinear, Victoria (13273) and Guthega Koscuisco, NSW (13287) hould be used.

A seedlot from Bowrall, ACT (10942) of E. macarthurii showed good growth and survival and it would be worthwhile establishing trial plantations with this seedlot.

A species that has shown much promise in both trials and small plantations in the lowlands and foothills is E. nitens. This year however there have been reports of increasing damage by Eucalyptus Snout Beetle. This may be attributable to the dehabilitating effect of a drought at the beginning of summer 1990-91 and the situation is being monitored. To date only moderate damage has been inflicted. It is recommended for planting in the lowlands and the foothills, but does not seem to be able to thrive in the harsh mountain conditions or on dry sites. In the absence of a trial in the foothills, where most E. nitens will be planted the seedlots which have performed exceptionally at Leshoboro Plateau should be imported again for establishment of plantations and seed stands. These were two Victoria seedlots; Nojee (12102) and Mt St Gwinear (12107) and one from Badja Mt in NSW (11861).

A species that has been successful at all trials, except for the unreplicated trial at Thaba Putsoa (See discussion) was E. stellulata. Of the four seedlots tested the Nimmitabel, NSW seedlot (11287) was shown to be most adaptable and had grown well at all sites. It is recommended that this species be used more widely from the lowlands up to sheltered mountain sites and that the Nimmitabel seedlot be used for future plantations of this species. The flowers of E. stellulata are known for providing good bee forage and hives could be established beside plantations of this species.

In the high foothills or on sheltered mountain sites Tasmanian E. viminalis, E. nova-anglica and E. dalrympleana should be planted. These recommendations agree with those of Pryor, (1973), with the exception of E. pauciflora, which has not performed particularly well in the trials.

The Swansea, Tasmanian (10073) seedlot only of E. viminalis should be established. Two seedlots are recommended of E. nova-anglica, that from Ebor Area, NSW (10717) and the SW Walcha, NSW seedlot (11677). For E. dalrympleana two seedlots are also recommended,one from Wiharega, Tasmania (11721) and the other from Cotter Hut Area, ACT (12097).

A slower, but species with potential is E. gunnii, which shows good survival and is known to be one of the most frost-hardy eucalypts. It is more cold-resistant than E. dalrympleana (references) and should be tested in small-scale plantings in the mountains. To date workers in France, through intensive selection within Tasmanian sub-alpine populations, have been able to produce clones of this species that will survive temperatures between -12°C and -20°C (Cauvin and Potts, 1991). Other work in France has shown there to be considerable intra-specific variation in E. gunnii (Destremau, 1983) and it may be that there are provenances more suited to Lesotho conditions than those tested to date. The foliage of E. gunnii is palatable and may be suitable for inclusion into agroforestry systems in the mountains, as a supply of winter fodder.

Species that should be investigated further also include E. fastigata and E. fraxinoides: one seedlot of each showed promise at a trial at Tsikoane Plateau. For E. fastigata the Barrington Tops and Oberon seedlots from New South Wales should be included.

Other species that would merit investigation in trials in Lesotho include; E. bicostata, E. delegatensis, E. dives, E. nicholii, E. niphophila, E. nortonii, E. ovata, E. regnans and E. youmannii.

The most important work to be done is the establishment of seed production areas of the promising species. It is only through these that sufficient quantities of cheap seed can be obtained and the results of these trials be of benefit.

In addition an exposed mountain trial should be established to test the eucalypts that showed good survival at Thaba Putsoa.

This is because Thaba Putsoa is a relatively sheltered site, and because grazing has been controlled there for many years and there are uncharacteristically deep soils with little erosion.

Other work should include testing the quality of these cold-tolerant eucalypt species as poles and fuelwood.

REFERENCES

Anon, (1976) Growing Eucalyptus. What's New in Forestry Research No 37. Forest Research Institute, Rotorua, New Zealand. 4p.

Anon. (1984) Eucalypts: Species Choice and Site Requirements. What's New in Forestry Research No 124. 4p.

Bazill, J.A. (1989) Summary of Research Trials in the Mountains. Unpublished internal report. Forestry Division, Lesotho. 8p.

Cauvin, B. and Potts, B. (1991) Selection for Extreme Frost Resistance on Eucalyptus. in Symposium on Intensive Forestry: the Role of Eucalypts, P2.02-01 Productivity of Eucalypts (Ed. A.P.G. Schonau). Durban, South Africa. p209-220.

Darrow, W.K. (1983) Provenance Studies of Frost Resistant Eucalypts in South Africa. in Colloque International sur les Eucalyptus resistants au froid. Published by AFOCEL, Nangis, France. p448-468.

Destremau, D.X. (1983) Introduction de l' _Eucalyptus gunnii_ en France, Premier resultants. in Colloque International sur les Eucalyptus resistants au froid. Published by AFOCEL, Nangis, France. p275-280.

Evans, J. (1983) Choice of Eucalypt Species and Provenances in Cold Temperate Atlantic Climates. in Colloque International sur les Eucalyptus resistants au froid. Published by AFOCEL, Nangis, France. p255-275.

FAO (1979) Eucalypts for Planting. FAO Forestry Series No. 11. 677p.

Jackson, J.K. (1987) Manual of Afforestation in Nepal. Nepal-United Kingdom Forestry Research Project, Forest Survey and Research Office, Department of Forests, Kathmandu, Nepal. p250-274.

Harwood, C.E. (1983) Studies on eucalyptus Frost Resistance in a Sub-Alpine Frost Hollow. in Colloque International sur les Eucalyptus resistants au froid. Published by AFOCEL, Nangis, France. p126-144.

Heywood, A.T. (1908) Report on Forestry in Basutoland by Conservator of Forests of King William's Town. 39p.

Lavery, M.; Seed Collection Expert, O' Connor Seeds, personal communication, January 1992.

Nixon, K.M. (1983) A Test of Fifteen Eucalypt Species and Provenances for Frost Resistance in Natal. in Colloque International sur les Eucalyptus resistants au froid. Published by AFOCEL, Nangis, France. p366-376.

Nixon, K.M. (1991) A Test of Fifteen Eucalyptus Species and Provenances on Two Sites in Natal - Some Bark and Timber Characteristics. in Symposium on Intensive Forestry: the Role of Eucalypts, P2.02-01 Productivity of Eucalypts (Ed. A.P.G. Schonau). Durban, South Africa. p258-265.

Orme, R.K. (1983) Natural variation in Eucalyptus gunnii Hook F. in Colloque International sur les Eucalyptus resistants au froid. Published by AFOCEL, Nangis, France. p63-79.

Poynton, R.J. (1966) Tree Planting in Basutoland. Forestry in South Africa No. 6. p33-48.

Poynton, R.J. (1979) Tree Planting in Southern Africa. Vol. 2 The Eucalypts. South African Forestry Research Institute. Department of Forestry. RSA. 882p

Poynton,R.J. (1986) Report: Choice of Tree Species for the establishment of woodlots in Lesotho. South African Forestry Research Institute, Pretoria. 14p.

Pryor, (1973) A Report on the Selection and Establishment of Tree Species Suitable for Pole and Fuel Wood Plantations in Lesotho. Consultancy Report for the United Nations development Programme and the Food and Agriculture Organisation of the United Nations. 12p.

Purnell, R.C. and Linquist, J.E. (1986) Provenance Variation of Eucalyptus nitens on the Eastern Transvaal Highveld in South africa. South African Forestry Journal. p23-31.

Quaile, D.R. and Mullin, L.J. (1983) Variation in Productivity of Eucalyptus nitens (Dean and Maid.). Maid. and Eucalyptus regnans F.Muell. in Zimbabwe. in Colloque International sur les Eucalyptus resistants au froid. Published by AFOCEL, Nangis, France. p383-393.

Richardson, K.F. (1980) Report on the First Assessment of 1979 Species/ Provenance Trials in Eucalyptus. Internal Lesotho Woodlot Project Report. 7p.

Richardson, K.F. (1985) Five Year Results of Species and Provenance Trials with Cold-resistant Eucalypts in Lesotho. Paper presented at the tenth regular meeting of the SARCCUS Standing Committee for Forestry held at Sabie, South Africa, on 20 to 24 May 1985. South African Forestry Journal, 135 . , December 1985. p43-52.

Richardson, K.F. and Meakins, R.H. (1986) Inter- and Intra-specific Variation in the susceptibility of Eucalyts to the Snout Beetle Gonipterus scutellatus Gyll. (Coleoptera, Curculionidae). South African Forestry Journal, no 139, December 1986. p21-31.

Schonau, A.P.G. and Gardner, R.A.W. (1991) Eucalypts for Colder Areas in Southern Africa.in Symposium on Intensive Forestry: the Role of Eucalypts, P2.02-01 Productivity of Eucalypts (Ed. A.P.G. Schonau). Durban, South Africa. p467-479.

Stanger, T.K. (1990) Project A1: Genetic Improvement of Eucalypts. Provenance Trials. Institute for Commercial Forestry Research, Annual Research Report 1990. p11 -24.

Turnbull, J.W. and Eldridge, K.G. (1983) The Natural Environment of Eucalyptus as the basis for selecting frost resistant species. in Colloque International sur les Eucalyptus resistants au froid. published by AFOCEL, Nangis, France. p43-62.

Van Wyk, G. (1983) Progress with the Breeding of Frost Tolerant Eucalyptus in South Africa. in Colloque International sur les Eucalyptus resistants au froid. published by AFOCEL, Nangis, France. p523-532.

Wilcox, M.D., Rook, D.A. and Holden, D.G. (1980) Provenance Variation in E. fastigata Deane & Maid. Paper presented to IUFRO Symposium and Workshop, Aguas de Sao Pedro Sao Paulo, Brazil. New Zealand Forest Service Reprint No. 1605. 10p.